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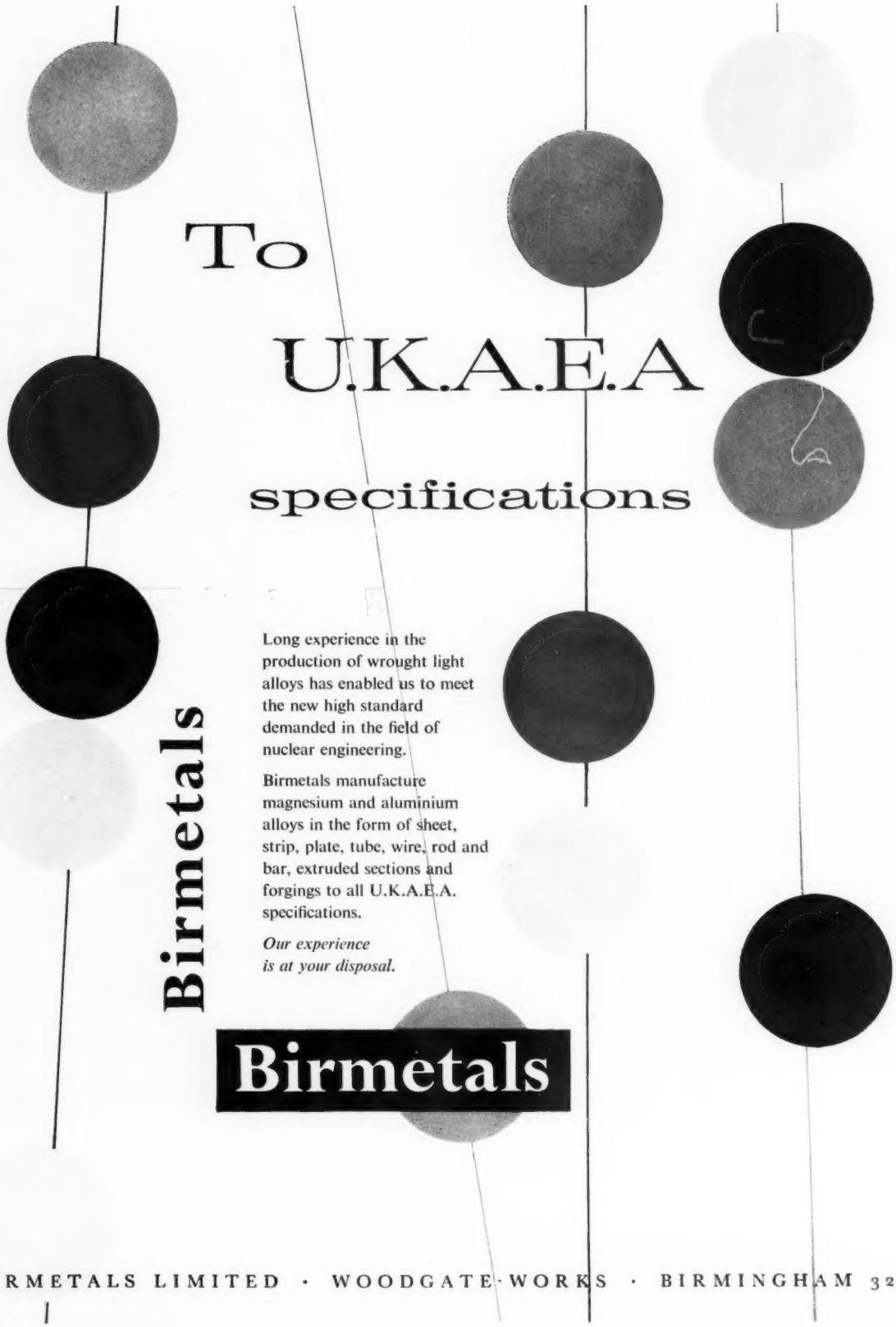

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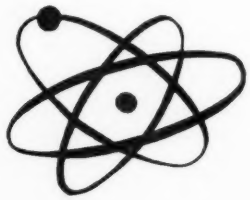
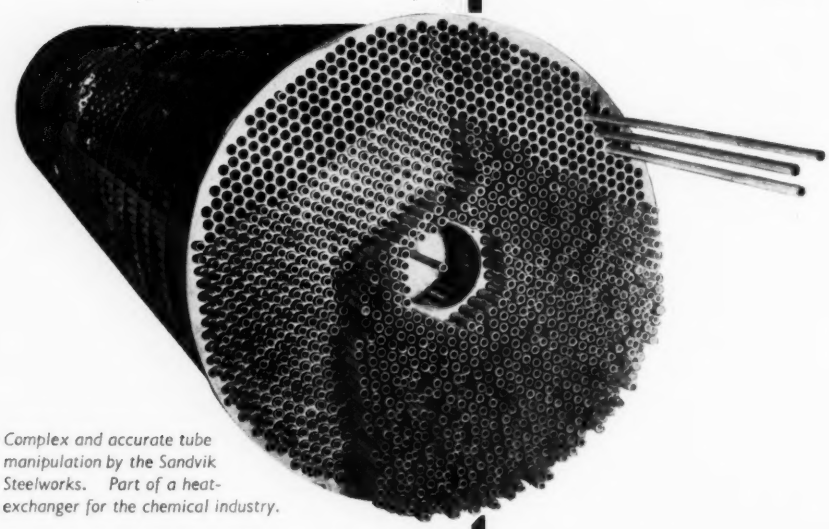


SANDVIK STEEL and nuclear energy



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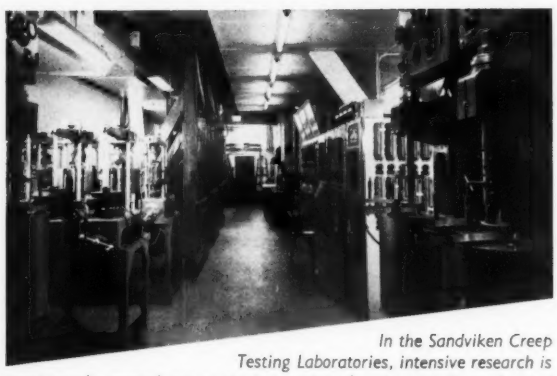

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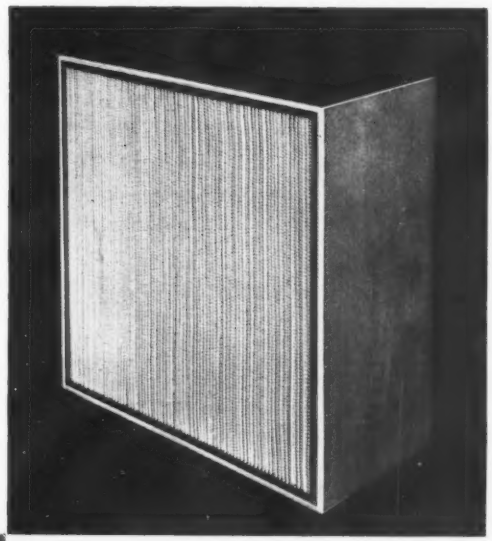

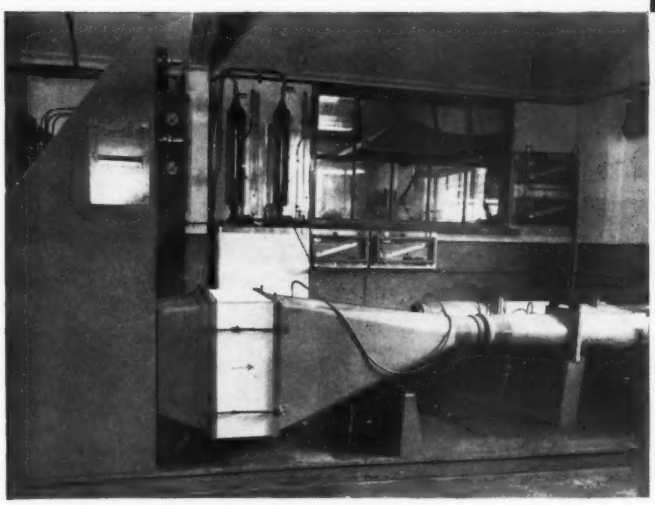

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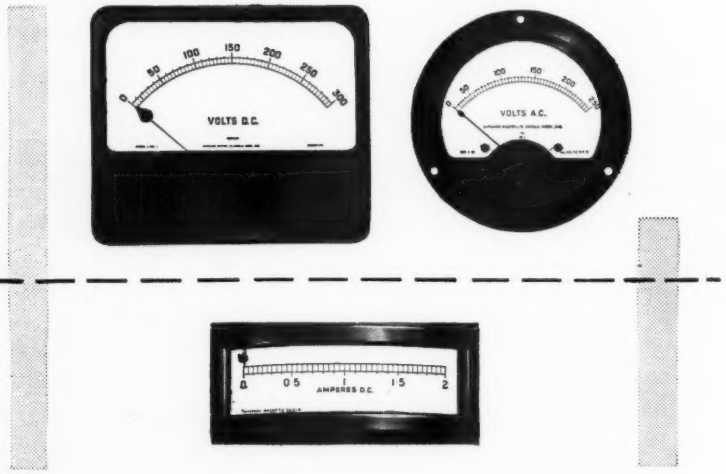

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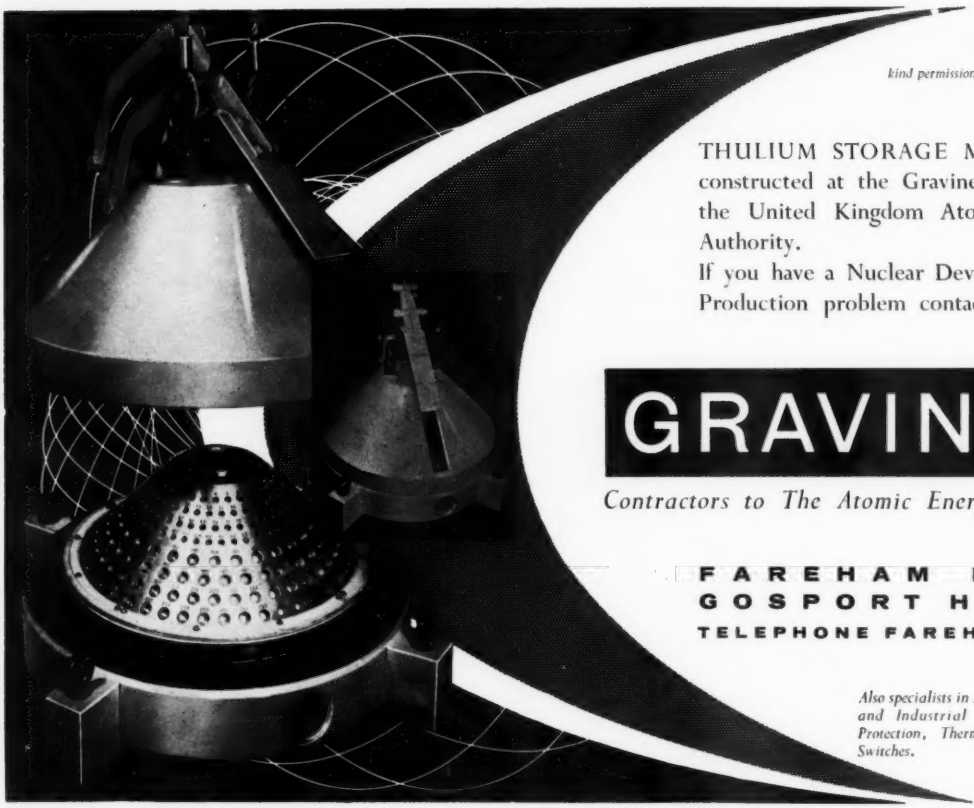

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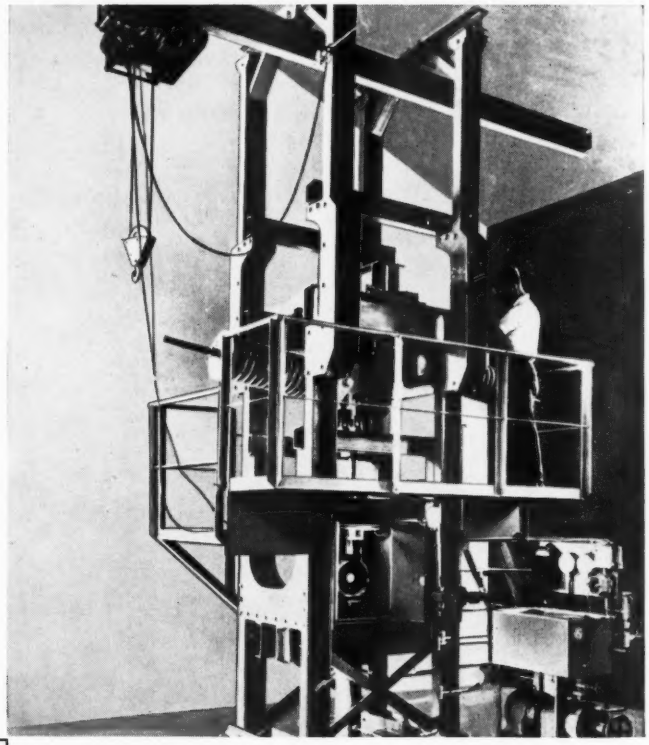

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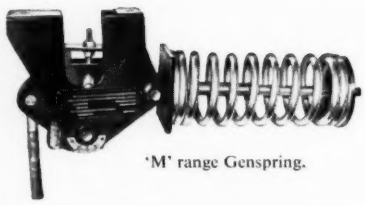

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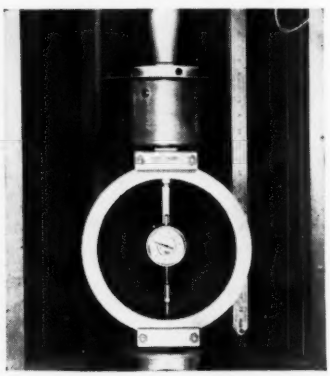

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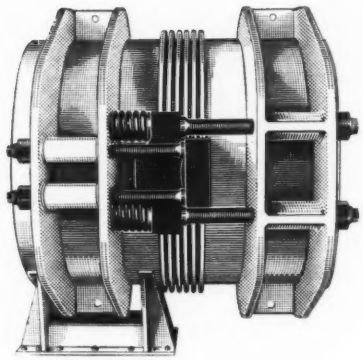

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NOVEMBER, 1959

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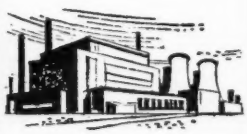

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At Hinkley Point, Newalls have been entrusted with the insulation of the reactors, steam raising units, gas ducting, integral piping, etc., under contract to Babcock and Wilcox Ltd

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Under contract to Babcock and Wilcox Ltd., Newalls are carrying out the insulation of the 16 steam raising units and integral piping. The insulation of turbines, blowers, associated auxiliary equipment and piping is being carried out under contract to C. A. Parsons and Co. Ltd.

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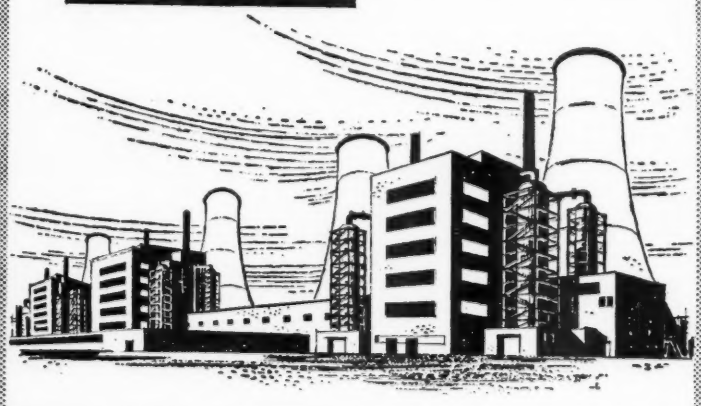
At Bradwell-on-Sea a further large contract for the thermal insulation of turbines, associated auxiliary equipment and piping (main and auxiliary turbine plants) has also been placed by C. A. Parsons and Co. Ltd. with Newalls.



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RADIATION and AGRICULTURE

PART II

by

F. R. PAULSEN, BSc, PhD, FRIC, FCS

Last month the author was mainly concerned with the use of radioisotopes as tracers. Here he describes their use in animal husbandry, as means of improving crops and breeds, and for controlling pests

(*Continued from page* 495)

ANIMAL husbandry, like plant physiology has been assisted by radioactive tracers. Radio-carbon has for instance been used to trace the role of acetate in the mammary gland of the cow, and the behaviour of glucose in the blood-stream. Sulphur in grass is used in the formation of hair and milk, iodine is very important for thyroid function, cobalt for the formation of vitamin B_{12}, and even copper seems to be essential to the healthy cow. Molybdenum has proved to be important to cattle, and can be found in milk. It is a constituent metal in an important enzyme. Vitamin B_{12} is synthesized in the rumen of the cow and sheep. The amino acids cystine and methionine are synthesized by herbivora from inorganic sulphate, which even the chick seems to be able to use for feather formation.

Physiology of Cow

In the cow, starch, cellulose and protein are broken down into smaller molecules by rumen bacteria. Among the degradation molecules are acetic, propionic and butyric acids, which are metabolized further. The acetic acid is incorporated into milk fat, propionic acid into liver glycogen, and butyric acid into β-hydroxybutyric acid. Of the ingested radiocarbon, 17 per cent. appears as acetic acid in the milk, 11 per cent. as propionic acid, and 6 per cent. as butyric acid. The majority of the remainder is in the form of glucose.

Scientist examines barley grown from irradiated seed

The β-hydroxybutyric acid, which is normally at a high level in the blood, gives rise to short chain acids to the extent of $2\frac{1}{2}$ times as much as does the acetic acid, and it is these short chain acids, comprising 20 per cent. of the milk fat, which give the fat its peculiar properties, so different from other oils and fats.

Radio-phosphorus has been used to trace the carrying of diseases by bees, and also in a study of the feeding habits of this insect. Migration of the bee, the wheatstem sawfly, boll weevil, pink boll worm, spruce beetle, pine weevil, and other insects has been traced by means of P32.

This bottle, connected to the lower part of tree, contains phosphorus-32 solution which is used to induce mutations likely to improve the tree's yield of fruit

Useful Mutations

Now, considering the application of the specific effects of radiations, we find that various types have been used in a wide range of fields. These include X-rays, gamma rays, beta-particles, fast and slow neutrons, and ultra-violet radiation. All these appear to produce the same types of mutations, many of which may be new to science. Although the natural incidence of mutations lies between 1 in 10^4 and 1 in 10^6, radiation can increase this to 10 per cent., thus enormously enhancing the rate at which genetic studies can progress.

Although formerly it was considered that all mutations were harmful, it is now known that this is far from the truth. Natural mutations are probably the result of cosmic rays; the density of this radiation, however, is probably too small to produce all the natural mutations, so that some other cause is probably active. The use of radiations has made genetic research much speedier than would have been

the case if science had to rely on observations on natural mutations only. For example, new rust-resistant species of rye have been developed in only 18 months, whereas 10 years would have been required for such a result had radiations not been used.

For centuries man has used cross-breeding from natural genetic mutations in order to produce cereals with improved yield. However, the exposure of grain and seeds to heavy doses of radiations has been found to increase markedly the mutation rate, causing chromosome breakage. The recombination of the fragments gives rise to chromosome patterns, resulting in mutations.

Improved Crops

Only one or two of the several hundreds of mutations prove available, but by careful selection, workers in Canada, Norway, Britain and U.S.A. in particular have obtained improved crops. The gamma radiation from Co60 has been applied to the early flowering stages or even to the seed, and progeny has been selected for its advantageous features. It has been possible to obtain plants showing increased resistance to pests and diseases, improved productivity in legumes and cereals, and better adaptation of cereals to mechanical harvesting. Strains specially suitable for early and for later development have been selected. Orchard crops, normally propagated by vegetative means, yield bud mutations on irradiation.

Although in Britain, Canada and U.S.A., workers have found that irradiation does not promote growth, Soviet workers have claimed increased growth and yield by four methods. In the first, to which cabbage, cucumber, radish and rye respond well, the seeds have been irradiated with doses of 100r. to 1,000 r. Secondly, if seeds were soaked in a solution of fission products with an activity of 0.2 mc/litre to 0.5 mc/litre, good response was shown by barley, bean, buckwheat, flax, haricot bean, lucerne, maize, melon, oat, soya, sugar beet, tomato, vetch, and wheat.

Soil is Treated

The third method consisted in treating the soil with isotopes at a dose rate of 10^{-9} to 10^{-5} c/kg. This was found to give good results with cabbage, clover, oat, potato, red beet, sunflower and wheat. Finally, buckwheat has responded to continuous irradiation of the crop by Co60, with doses of 0.9r. to 116r.

The "Atomic Garden"

At the USAEC's Brookhaven Laboratory, mutations have been produced by means of the "atomic garden" or "gamma field," and others by the use of neutron fluxes in the thermal column of reactors. Mohawk oats, normally susceptible to rusts, have been made resistant, without any deterioration in yield, and the strains have bred true for five generations.

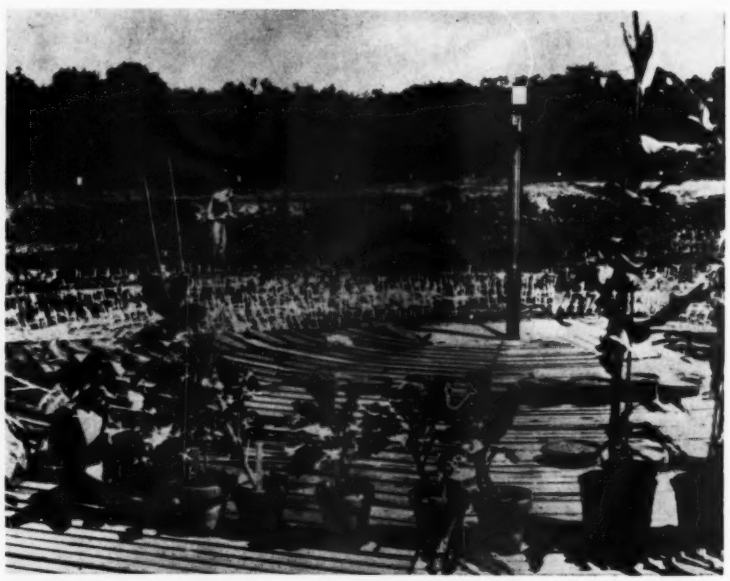
Oats have been produced with short strong straw and wide leaves, better able to withstand the high winds such as are prevalent in Texas.

It must not be assumed that all results are equally beneficial. In some cases plants have been produced with resistance to blight, but less resistant to rusts. However, careful selection has been able to cut down the millions of dollars lost annually in the U.S.A. through crop destruction. Resistance to stem rust has been induced in wheat, oats and barley, while wheat has been made immune to stripe and leaf rusts, barley to mildew, and oats to Victoria blight. Control over fusarium wilt has proved possible. In Sweden, commercial barley is now available with stiff straw, and peas with high yield. In Germany, the bitterness has been bred out of lucerne, which is thereby rendered suitable for an animal feeding-stuff.

Although the most striking results of radiations are those arising from changes in genetic cells, via chromosome damage, changes in the somatic cells are not ruled out. In fact, various irradiations have led to modifications in colour, changes in form of leaf and flower, inhibition of growth, meristem stimulation, formation of multiple vegetative apices, production of chimeras, precocious flowering, reduction of fertility, changes in food reserves, and so on. Much still remains to be done in differentiating between the effects of internal radiations due to radioactive materials in the organism, and those of external radiations.

Other Influences

It will also be necessary to find ways of modifying the effects of radiations through changes in environment and pre-treatment of the genetic material. Such changes might include composition of the atmosphere, temperature, moisture, soil, presence of neutron-absorbing elements, and treatment with

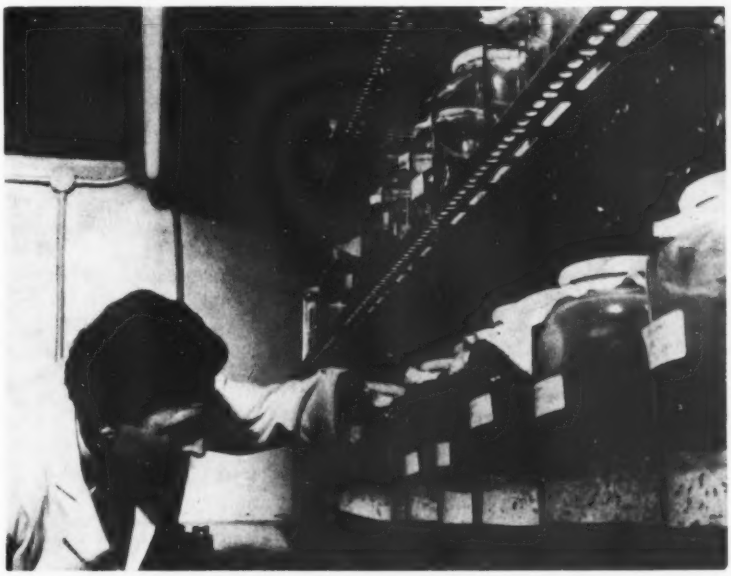


The "Atomic Garden" or "Gamma Field" operated by the Brookhaven National Laboratory, New York, where experiments are conducted into ways of improving crops by radiation-induced mutations. The plants seen in this illustration are exposed to the rays from a cobalt-60 capsule mounted on a vertical pole. The capsule is lowered when gardeners work within its vicinity

chemicals before irradiation. Radiation should also enable workers to use chromosome aberrations to break undesirable linkages between the beneficial genes and deleterious ones. Such included changes as aneuploidy, haploidy, and polyploidy may offer many possibilities to the geneticist.

Pest Control

The damaging influence of radiations has been used in the control of pests in agricultural products. Thus, weevils in wheat and other grains are destroyed by radiation doses of 10,000 rep. to 50,000 rep. The effect is irrevocable to their reproductive functions. Doses of 10,000 rep increase the storage time of potatoes and onions by preventing sprouting in spring and summer. Sterilization is possible by the use of pure radio-elements such as Cs138, or Co60, or by bulk fission products, or even spent fuel elements.



A scientist at the Isotopes Division, AERE, Harwell, examines flour mill moths used as test insects in the irradiation of flour

Screw-worms which infest the wounds of livestock are eliminated by irradiations aimed at making the male worms sterile

One very interesting method of pest control has been used in Curaçao to combat the screw worm which is parasitic on various domesticated and wild animals. Large numbers of male flies were rendered sterile by irradiation with the gamma rays from Co60, and then released. Mating would, of course, result in no offspring, and after a few generations the considerably reduced reproduction of the species resulted in their annihilation. While such a control method might be applicable to other insect pests, it does presuppose a number of factors which may not be always practicable. It requires facilities for large scale irradiation of insects, and for their breeding, an isolated community such as was presented by the island of Curaçao, a favourable genetic cycle, and knowledge of migration habits and the life cycle.

An insect culture room at Harwell

Conclusion

This survey, while by no means exhaustive, is indicative of the extremely wide range of applications of radioactive isotopes in the field of agriculture and farming in general. It also points to the yet unharvested benefits still to come, benefits which could well tip the scale in favour of a balanced foodstuffs economy throughout the world, rather than the present unbalance of excessive crops in some parts of the world and starvation in others. Bigger and better crops are within man's grasp, and agriculturalists should be able to conquer in time the various diseases and climatic effects which are at present limiting the value of crops. Atomic energy has much to offer the agriculturalist, provided nature does not hit back by producing more and more resistant viruses, insect pests and bacterial diseases. There may be a fight for still a long time to come, but man is better armed now than ever before.

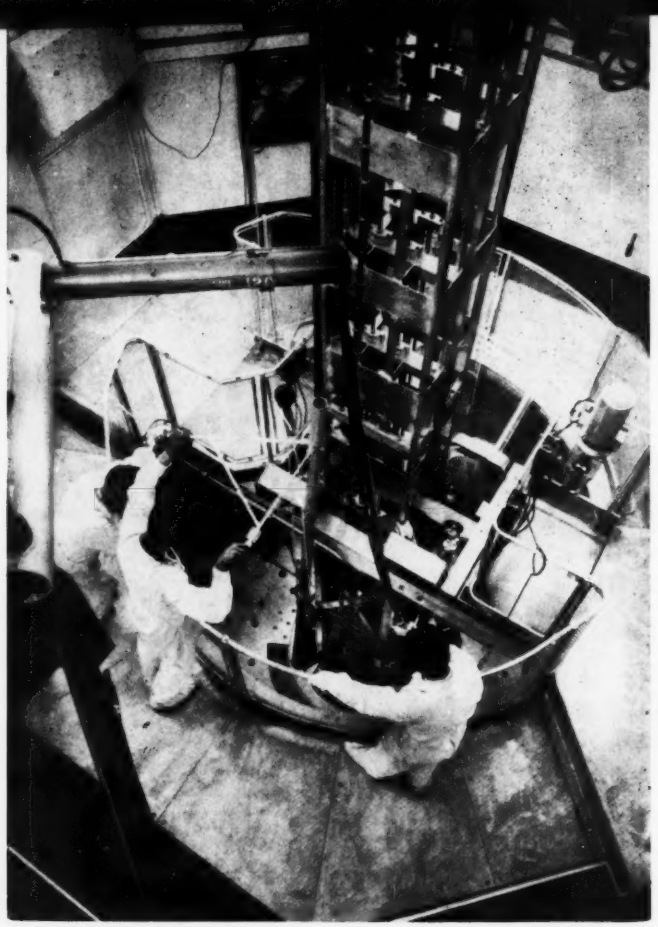
Photographs used to illustrate this article were supplied by the United Kingdom Atomic Energy Authority and the United States Information Services.

MERLIN

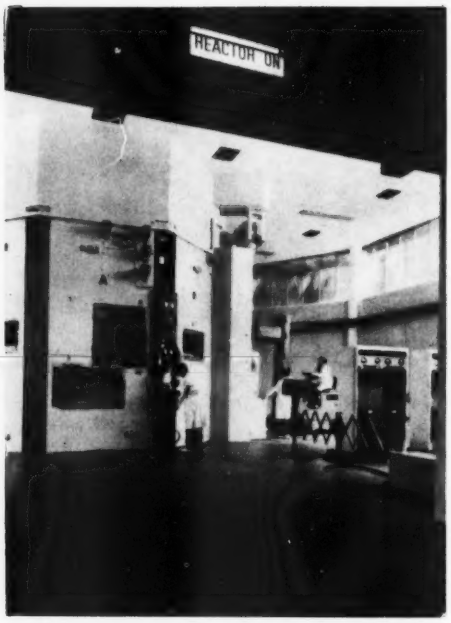
BRITAIN'S FIRST

FORMAL OPENING

Prince Philip is to visit Aldermaston Court, headquarters of nuclear research carried out by Associated Electrical Industries Ltd., during early November to open for scientific research MERLIN, which recently went critical. This article describes some of the features of this interesting research reactor.



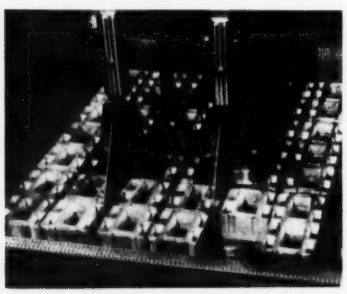
Top of the reactor. Vertical structure in centre supports the core-carrying mechanism which enables the core to be moved vertically to any of four positions inside the reactor tank



Ground floor level of the reactor building showing MERLIN shielding and the experimental ports. On the right can be seen local controls used during certain experiments. Control room proper is behind these, out of the picture

MERLIN is the first nuclear reactor in the United Kingdom to be operated by a commercial organization. It was built to enable Associated Electrical Industries Ltd., the owners, to expand their research and development work in the fields of fundamental and applied nuclear science. It also serves as the prototype of a saleable product; already two similar reactors are being built for other organizations.

MERLIN is installed at the AEI research laboratory, Aldermaston Court, in Berkshire, near the Atomic Weapons Research Establishment. Aldermaston Court consists of a country house with extensive grounds, including a large and attractive lake which supplies the water used for cooling the reactor. AEI have been carrying out nuclear physics research there since 1946. As the work has expanded so new buildings have been added, the latest being an up-to-date, fully equipped physics laboratory.



Fuel elements in the sub-critical assembly. Experiments in this have provided information on core behaviour which has been used for MERLIN

The reactor and its ancillary equipment and plant occupy buildings specially constructed for the purpose on a 40,000 sq.ft site on the house side of the lake. There is plenty of room for the site to expand.

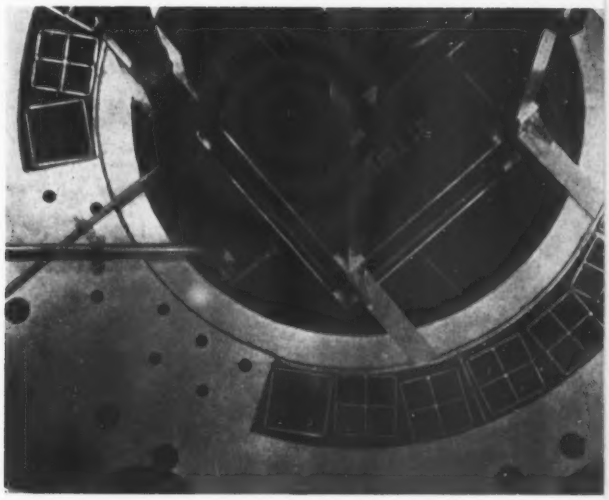
A decision to build MERLIN, which is a natural-water cooled and moderated reactor fuelled with highly enriched uranium, was made in 1955. Construction was put in the hands of the AEI-John Thompson Nuclear Energy Co., Ltd., the company which is building the nuclear power station at Berkeley, Gloucestershire. They were helped in the design and commissioning of MERLIN by the staff of the Aldermaston Laboratories. The reactor went critical in July, 1959. Thermal, mechanical, electrical and physical tests are now being carried out on it. These will continue until a thermal reactor power of 5 MW is reached.

The research programmes planned for MERLIN include:—

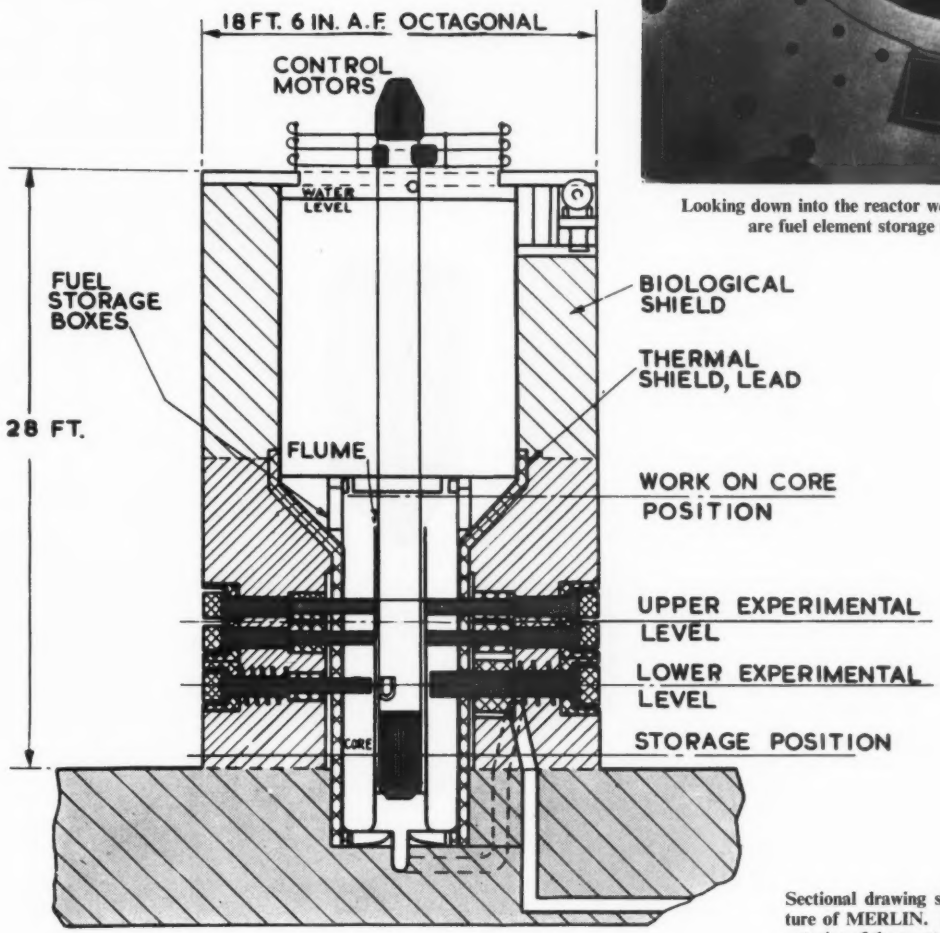
1. The study of the effects of radiation on materials;

PRIVATE REACTOR

BY H.R.H. PRINCE PHILIP



Looking down into the reactor well. On the perimeter are fuel element storage facilities



Sectional drawing showing basic structure of MERLIN. In cross section the exterior of the reactor is octagonal. The shielding, which is 3 ft 5 in. thick at the top and 5 ft 8 in. thick at the bottom is of barytes concrete for the first 14 ft 6 in. and Portland concrete for the rest of its height. The tank contained within the shielding is fabricated from $\frac{1}{4}$ in. thick aluminium. It is in two parts joined by a conical section. The diameters of the two parts are respectively 11 ft 6 in. and 5 ft 6 in. The four positions to which the core can be moved are clearly shown. The core contains about 4.5 kg of U-235 in a 90 per cent. enrichment. Maximum heat output of the reactor is 5 MW, maximum thermal flux, 5×10^{13} n/cm²/sec, and maximum epithermal neutron flux 2×10^{14}n/cm²/sec

2. The study of Cerenkov radiation in reactors;

3. The provision of nuclear data and methods of measuring neutron spectra;

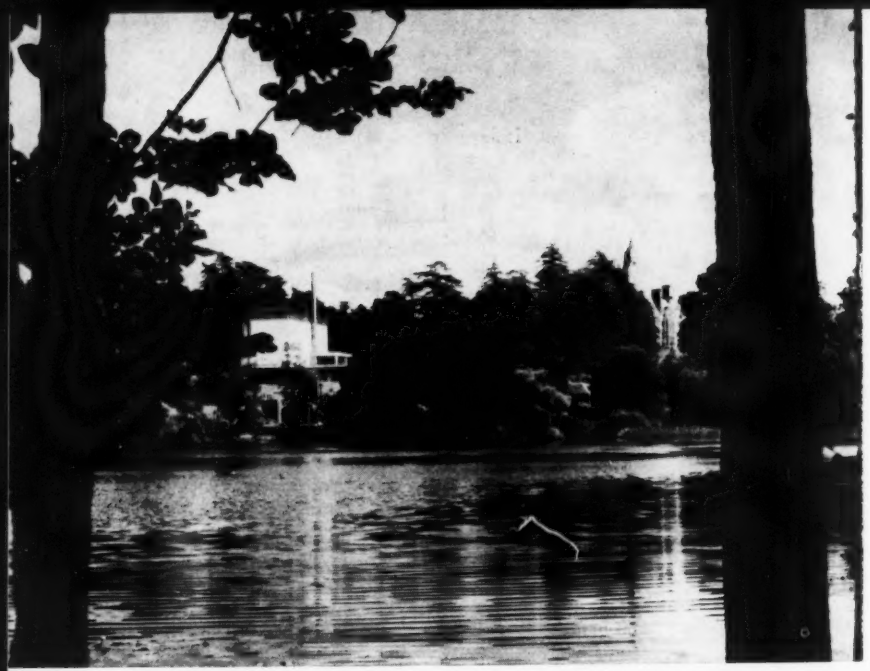
4. Activation analysis;

5. Reactor control and safety studies;

6. The production of short-lived radioactive isotopes.

MERLIN will also play its part in the training of nuclear and reactor physicists and engineers. To this end some of the reactor facilities will be made available to various universities, who will also be able to carry out experiments with it.

When selecting a reactor system best suited to their purposes, Associated Electrical Industries had to consider the need for designing a reactor that was, first and foremost, safe. Secondly, they required a reactor which was simple to operate and which would be useful not only for research purposes but also for training personnel. Also to be considered was the necessity to



View across the lake showing the MERLIN reactor buildings and part of Aldermaston Court. A closer view of the reactor buildings is shown below

keep the construction and installation costs of the reactor to a minimum, a particularly important point if the reactor was to be sold commercially.

The light water cooled and moderated reactor using highly enriched uranium as fuel was considered the most likely type to fulfil these requirements. Such a reactor can provide relatively light fast and thermal fluxes for a given power. In addition, the primary water system does not have to be so complicated as in the heavy water moderated and cooled reactor.

Also, the negligible cost of light water contributes to making the initial capital investment smaller.

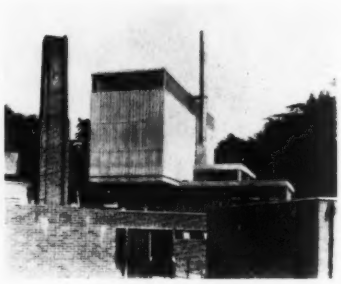
The tank containing core and moderator in the light water reactor can be either enclosed or open. The open tank was chosen for MERLIN because it enables the core region to be seen while the reactor is operating. Also it permits easier handling of the core components.

A further refinement in the overall design is the use of a well-shaped tank rather than a "swimming-pool." This enables the reactor building to be smaller, resulting in lower capital costs.

MERLIN basically consists of a vertical aluminium tank divided into two parts joined by a conical section. The top part is 11 ft 6 in. in diameter and the bottom part in 5 ft 6 in. across. The whole is surrounded by concrete which is 5 ft 8 in. thick for the first 10 ft 2 in. above floor level and 3 ft 5 in. thick from this height to the top of the reactor and 3 ft 5 in. thick from this height to the top of the reactor, 28 ft above floor level. Barytes concrete is used for the first 14 ft 6 in. of the shield, Portland concrete for the rest.

The core can be moved vertically inside the tank to any one of four positions. When it is in the top position fuel elements and experimental components can be added and withdrawn. In two of the lower positions the core is brought opposite experimental ports through which various tests and experiments can be carried out. The fourth and lowest position is used for storing the core and is so arranged that the possibility of loss of coolant from the tank in this region is negligible.

The MERLIN fuel elements are essentially similar to those used in other water cooled research reactors in the United Kingdom. Each standard element comprises 14 active plates, $2\frac{7}{8}$ in. wide $\times$ 25 in. long, made up of a nominal 10 g. of U-235 in the form of an aluminium-uranium alloy which is completely sealed in an aluminium cladding. There are also two blank plates to each element. All 16 plates are



Drawing showing layout of the MERLIN reactor building and ancillary installations. Key:—1 Reactor building; 2 Control room; 3 Delay tank; 4 Primary water circuit pump house; 5 Secondary water circuit pump house; 6 The lake; 7 Water demineralization plant; 8 Boiler house; 9 Laboratory for sub-critical studies; 10 Effluent treatment plant; 11 Personnel change room; 12 Active storage area; 13 Laboratories and offices

Dr. T. E. Allibone, FRS *Director of Research*

MERLIN is not the only experimental facility at Aldermaston. There are two particle accelerators, for instance, and apparatus for plasma studies. In charge of all this work is Dr. T. E. Allibone, FRS, who has built up a formidable team of scientists and engineers. Those responsible for MERLIN are shown here

bronzed together to form a box. Partial fuel elements with one, two, four and six plates are also available so that the amount of U-235 in the core can be adjusted in 10 g. steps.

The minimum cold, unpoisoned critical mass of the core is 2.66 kg of U-235.

The reactor has four control elements, arranged as one coarse control element, one fine control element, and two safety elements. The coarse and safety elements are driven by three-phase induction motors through gear boxes, and rack and pinion mechanisms. Emergency release of the elements is effected by de-energizing holding magnets. The fine control element is driven by a series connected split field d.c. motor. It may be controlled manually or automatically.

A large number of experimental facilities are available in MERLIN. They are set at two levels so that one set can be in use whilst modifications are being made to experiments at the other level.

Holes through the shield can be used either for radiation beam experiments or for irradiation type work. There are two thermal columns at the lower experimental level, both of which can be used either as sources of thermalized neutrons or as irradiation facilities. One of the columns contains four 4 in. square holes; the other, three. The holes can be filled with graphite, if the column is to be used solely as a large thermal neutron source, or with experimental equipment.

There are two 6 in. tubes at the upper level which go straight through the reactor to pass close to the core.

A shelf is provided at the upper experimental level between the tank and flume for the irradiation of units larger than can be accommodated in the experimental holes. Direct access to this shelf is available from the top of the reactor as is access to two vertical tubes 6 in. × 3 in. that pass down the edges of the core and end at the level of its lower face when it is at the upper experimental position.

Vacant positions in the core lattice can also be used for irradiations.

Water used as coolant, moderator and as partial shielding in the reactor passes from the reactor tank through a 100 sec delay tank of 2,950 gal capacity. It then passes through four heat exchangers and from these some of the water is bypassed through Swansdown-ceramic filters and a mixed-bed demineralization plant. Before returning to the reactor the water passes through a conductivity meter and orifice flow meter; when the reactor power is greater than 100 kW the latter causes a shut-down when the flow is insufficient.

Water used in the secondary circuit, which carries away heat removed from the primary circuit by the heat exchangers is drawn from Aldermaston lake through coarse filters and through two motorized valves in parallel. The outlet from the heat exchangers returns to the lake through a third motorized valve. The three motorized valves are automatically closed if a reactor shut-down is initiated by a fission product detector in the primary

(*Continued on page 563*)

THE MERLIN TEAM

Mr. D. C. Chick *Leader, Nuclear Sciences Group*

Dr. A. Salmon *Leader, Reactor Section*

Dr. K. Frith *Senior Reactor Physicist*

Mr. B. Millar *Senior Control Engineer*

Mr. I. Munro *Senior Mechanical Engineer*

Mr. M. Kerridge *Reactor Supervisor*

Brig. I. Reeve *Senior Reactor Operator*

Maj. C. Eastes *Reactor Operator*

More protection for hands and machines–

New Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, the Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

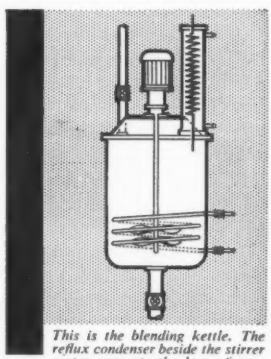
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors to produce the right oil for the job. If you and your organization have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.



This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

another proof of Shell leadership in lubrication

THE DISPOSAL OF RADIOACTIVE WASTES INTO COASTAL WATERS*

For about five years, experimental discharges of radioactivity have been made from the United Kingdom Atomic Energy Authority's Windscale Works, Sellafield, to the coastal waters off Cumberland. Samples of fish, seaweed, sea bed and shore sand have regularly been taken and their activity assessed. This report summarizes the results of that programme and concludes that the maximum permissible discharge rate is not less than 20,000 curies per month of total beta activity. Specific limitations are necessary for strontium-90, for ruthenium-106 and for plutonium. This information can be of use in estimating the safe discharge into other coastal waters.

by

H. J. DUNSTER,

UKAEA Industrial Group

Part I—Preliminary Studies at Windscale

MANY of the processes and laboratory operations associated with a nuclear power programme produce radioactive liquid wastes, which may be dealt with by any of a large number of variants of two basic procedures. These procedures are storage, preferably in a highly concentrated form, or dispersal into the natural environment.

The main fission product wastes of a nuclear power programme are of such high activity that only storage, either in controlled conditions, or in natural regions of isolation, can be considered. However, in addition to these high activity wastes, there arise substantial quantities of wastes in which the radioactivity is very dilute. Treatment of these wastes so as to concentrate the activity in a form suitable for storage is not always an economic proposition and dispersal into the environment under carefully controlled conditions is often a more satisfactory way of disposal. In the United Kingdom, hospitals, factories and laboratories which use radio-isotopes discharge much of their liquid waste to sewers and rivers under control enforced by existing public health legislation.

The only large scale disposals of radioactivity are those made by the United Kingdom Atomic Energy Authority and special legislation has been devised to control these disposals. Under this legislation, the Atomic Energy Authority is permitted to dispose of radioactive waste only in accordance with specific authorizations issued by two departments of Her Majesty's Government. These departments appoint inspectors who have right of access to the Atomic Energy Authority's premises to satisfy themselves that the authorizations are being complied with.

At present only one series of discharges under these authorizations is on a substantial scale and this is the discharge of aqueous waste to the sea from Windscale Works at Sellafield in Cumberland. The waste consists of dilute aqueous solutions which are neutralized immediately prior to discharge, the radioactivity is thus not necessarily present in genuine solution, but may be in the form of a very dilute suspension. The wastes are discharged to sea through a pipe line extending about 3 km beyond the high water mark.

Problem Simplified

When the design of Windscale Works was first being considered, it was recognized that it might be convenient to discharge a few hundred curies/month in the form of liquid waste, and the choice of a coastal site greatly simplified the disposal problems. Discharges of radioactivity of this magnitude cannot be considered, even into the sea, without a detailed preliminary investigation and review of the possible problems. Approximate numerical assessment of these problems, is possible and will normally indicate that some of them are predominant while others can be dismissed as insignificant. The relative importance of these problems will depend greatly on the details of the local marine environment and on the extent to which marine resources are exploited for man's use.

Dye was Used

At Windscale the preliminary work started with hydrographic studies of the diffusion processes and the tidal streams. The diffusion studies were undertaken by releasing large quantities of dye at various points off the coast and sampling the resultant patch from ships during the following few hours. From the rate of spread of the dye and from its rate of dilution it was possible to estimate diffusion co-efficients and ultimately to decide on the length of pipeline required to avoid high concentrations on the shore. This work was reported at the 1955 Geneva Conference by Seligman[1].

Tidal stream studies were made using current meters and drift markers and showed that although there was considerable tidal movement in the area there was little or no residual current. This conclusion was subsequently confirmed by studies of the distribution of salinity in the north-east Irish Sea. These studies showed that the removal of fresh water running off the land was predominantly by eddy diffusion rather than by currents. There was, of course, considerable movement of surface water as the result of winds. This movement did not greatly

*Paper presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958.

affect the bulk transfer of water, but it did contribute considerably to the turbulence.

Three Main Dangers

The preliminary assessments showed only three main potential dangers. These were radioactivity in edible fish and in edible seaweed and radiation from the shore. Other risks, such as irradiation of bathers, ingestion of sand or sea water and the use of seaweed as a fertilizer, were shown to be of a lower order of importance. The work was, therefore, concentrated on estimates of the probable relationship of the activity of fish, seaweed and sea shore with the activity of the sea water.

Programmes of work were started on the distribution and commercial capture of edible fish from the region of the proposed pipeline and on the distribution of edible seaweed along that part of the Cumberland coast. The study of fish movement involved the capture and marking of over 35,000 fish in the pipeline region. Some of these fish were recaptured in a planned fishing programme while others were returned through commercial channels. Nearly half the marked fish were subsequently recaptured.

Effect of Incoming Fish

The results showed that the fish made small seasonal movements, probably governed mainly by temperature changes, and that when they left the area very few of them travelled further than the limits of the North Irish Sea. The proportion of marks in the commercial landings indicated that there would be a considerable dilution by fish from areas remote from Windscale. The studies of seaweed suggested that no great dilution with inactive weed could be relied upon since the Cumberland weed was harvested only over about 40 km off the shore line and all of it was sent to one area in South Wales, where it formed a considerable fraction of the total supply.

These environmental studies were supported by laboratory work in which fish and seaweed were kept in tanks of sea water to which radioactive materials had been added. Regular sacrificing of the fish and sampling of the seaweed enabled estimates to be made of the concentration factor between sea water and the edible materials. Measurements were also made of the concentration in fish and seaweed of inactive elements which were expected to appear in active forms in the effluent. A comparison of these concentrations with the natural concentrations of the elements in the sea water enabled a further estimate to be made of the maximum concentration factors which could be expected.

Vertical Mixing

The results of these preliminary studies showed that the effluent would leave the pipeline and would be rapidly mixed with large volumes of the sea water which, off this part of the coast, undergoes complete vertical mixing. The diluted radioactivity would then be carried up and down the coast by the tidal stream and would slowly diffuse into the whole of the northern Irish Sea and would finally pass out into the Atlantic Ocean. Only in the area within a few kilometres of the outlet would the activity concentration be significantly different from the natural background activity of sea water.

The coastal water off Cumberland is heavily loaded with suspended solids including sand, mud and organic detritus. During the process of dilution much of the radioactivity would become adsorbed on to this suspended matter and on to the sea bed and to a lesser extent on to the sea shore and seaweed. The fish which live off this part of the Cumberland coast are those which live on the sea bed and of these plaice, *Pleuronectes platessa*, are the most important. These fish would take up activity, partly from the water, partly from the solid particles amongst which they live, and partly from their food, which consists mainly of invertebrates living on the sea bed.

Predictions Vague

These various concentration processes were expected to cause the activity of sand, seaweed and fish to reach 10 or 100 times, or exceptionally perhaps 1,000 times, the activity concentration in the sea water. No precise predictions were possible because it was impracticable to reproduce the natural conditions on a laboratory scale.

By combining these forecasts with estimates of the maximum premissible activity levels in fish and seaweed and on the shore, it was possible to assess the maximum permissible discharge rate. A deliberate factor of safety of 10 was introduced into the calculations because of the uncertainty of some of the predictions. From this work, which was reported at Geneva in 1955 by Dunster[2], it was concluded that a discharge of about 100 curies/day of beta activity and of about 0.1 curie/day of alpha activity would be completely safe.

The preliminary studies had included no discharges of radioactivity because it was recognized that such discharges were unlikely to produce useful experimental results unless they were continued for a period of some months. However, by 1952 it was possible to make such regular discharges from Windscale and it was decided to combine these with a detailed monitoring programme to form a planned experiment.

Safe Discharges Made

This experiment, whose aim was not only to show the safety of the discharges, but also to establish the values for the maximum permissible discharges, was supported by the Ministries responsible for issuing the authorizations for waste disposal. Since that time, the discharges have been deliberately maintained at a level below the authorized rate, but high enough to obtain detectable activity levels in samples of fish, seaweed and shore sand.

The main monitoring effort during the period since 1952 has been concentrated on measuring the activity of fish, seaweed, shore sand and sea bed. A few attempts have been made to estimate the activity of the sea water but the presence of finely divided solid matter in suspension makes the interpretation of such results very difficult.

The aim of the monitoring programme has, therefore, been directly to relate the activity in the materials with which man comes in contact to the rate of discharge of radioactivity. It has not, therefore, been possible to compare the results of the monitoring programme step by step with the results of the preliminary studies.

The samples of sand from the shore have been assessed for total beta activity since only the beta, and to a lesser extent the gamma, radiations from the shore are of importance. Sea bed samples have also been

assessed, partly because the sea bed may contaminate fishing gear, but also because the distribution of activity reflects the dispersal of the active effluent in the sea water.

Both fish and seaweed are used for food and, because of the wide range of toxicities between such materials as plutonium, strontium and other fission products, analytical methods have been used to make separate estimations of plutonium, strontium, ruthenium and total beta activity. The total number of determinations involved in this monitoring programme has increased from about 250 per year to about 1,000 per year. In addition to these environmental measurements, samples have been taken from the outgoing effluent. A sample of each discharge has been assessed for total beta activity for plant control purposes and a representative sample has been bulked and given a detailed analysis every month.

The permissible activity level in the marine materials sampled depends both on the isotope concerned and on the part the material plays in man's life. The basic standards which have been used in the studies at Windscale Works are those recommended by the International Commission on Radiological Protection, in particular those recommendations published after the meeting in 1953[3]. The figures given by the International Commission relate primarily to the exposure of radiation workers who are under medical supervision, and these figures have been reduced by a factor of ten before applying them to members of the general public.

Time on the Beach

In estimating the permissible activity of the shore sand, it has been assumed that nobody regularly spends more than 100hr/year on the sands and that a dose of 1.5 rads/year is a permissible annual dose for the mixture of beta and gamma radiation involved. The samples have been assessed by beta counting on a thick source and the results have been calibrated in terms of the concentration of potassium-40 which would give the same counting rate.

The permissible level adopted for shore samples assessed in this way was 2.5×10^{-2} microcuries/gm dry weight which, for a deep and extended layer of contaminated sand, represents a dose of slightly less than 1.5 rads in 100hr. The use of the dry weight of the sample introduces a small safety factor. Since most of the dose will be delivered by beta radiation, the figure of 1.5 rads/year also contains a small safety factor. Neither of these factors has yet been taken into account.

Silt Deposited

The samples have been taken at points up to a distance of a few kilometres from the point nearest the outlet, but the distribution of samples has been weighted by more frequent sampling near the outlet. In calm weather, a fine black silt settles out on parts of the sand and remains until it is removed by heavier seas. The deposits are localized and shallow and the radiation dose they deliver will not be likely to exceed the figure of 1.5 rad/year provided the activity level remains below about 1×10^{-1} microcuries/gm.

Radioactivity on the sea bed is no direct danger to man but because of the possible contamination of fishing gear a limit of 1×10^{-1} microcuries/gm has again been set. This value has been based on experimental measurements of radiation levels from fishing gear used near the effluent outlet. The sea bed samples have been taken within a few kilometres of the outlet mainly within the narrow band parallel to the coast where most of the activity is deposited.

Fish Consumption

The permissible activity of fish depends on the consumption of locally landed fish, not all of which is caught in the vicinity of the effluent outlet. However, because of the very low activity levels, it has not been feasible to monitor these fish directly and the fish samples have, therefore, been obtained by trawling in the area within a few kilometres of the outlet.

A few people in Cumberland eat an average of about 250 gm/day of local fish, but as only a small proportion of this comes from the area near the outlet, the maximum permissible level in the fish samples has been based on a daily consumption of 25gm. The international recommendations for the maximum permissible concentrations in drinking water assume a daily consumption of 2,200 gm of water and the maximum permissible concentration in fish samples has, therefore, been set at 100 times the permissible level for water consumed by members of the general public, that is, at ten times the maximum permissible level for water consumed by radiation workers.

Limits for Seaweed

A similar assessment has been made of the consumption of seaweed and it has been found that a few people eat an average of as much as 75 gm/day. No allowance has yet been made for dilution by seaweed from areas remote from Windscale and the sampling programme has been used to obtain an estimate of the average activity of seaweed from the whole Cumberland coast. The maximum permissible concentrations in seaweed are, therefore, set at 3.3 times the corresponding maximum permissible concentrations in drinking water for consumption by radiation workers. Disregarding the dilution by inactive weed introduces a safety factor which is unlikely to be less than two.

While these estimates of the maximum permissible activity of fish and seaweed are adequate for specific isotopes, measured by specific chemical methods, they need further consideration for samples assessed for total beta activity. Such samples are counted as thick sources and the results are thus dependent on the beta energy of the contaminant.

Potassium-40 is again used as a standard. Much of the activity has been contributed by ruthenium-106 and part of the remainder is due to cerium-44. Both these isotopes have maximum permissible concentrations in drinking water of 1×10^{-4} microcuries/millilitre but both have beta energies in the region of 3 MeV and are overestimated in the thick source by a factor of about two. Other contributing isotopes will not be overestimated but have permissible concentrations of 2×10^{-4} microcuries/millilitre or more. The permissible activities of fish and seaweed have, therefore been based on this value of 2×10^{-4} microcuries/millilitre in drinking water, although it involves a small safety factor because of the presence of less toxic isotopes.

Treated Separately

Since Ru106 is a major constituent of the discharges, it is more satisfactory to treat this isotope separately rather than to associate it with the rest of the beta emitters. Many of

the fish and seaweed samples have, therefore, been assessed for Ru106 as well as for total beta activity. In these cases there is no difficulty in assigning a value for the maximum permissible activity due to ruthenium, but a difficulty arises in defining both the activity level and the maximum permissible activity due to beta emitters other than Ru106.

Method of Counting

The expedient adopted in this work has been to estimate total beta activity by counting a thick source, with K40 used as a standard, and to subtract from it the value which the Ru106 would have given if it had been assessed in the same way and not by chemical separation and counting as a thin source. The difference value obtained in this way is referred to as the total activity excluding Ru106, and the maximum permissible level which is applied to it is that derived from a value of 2×10^{-4} microcuries/millilitre in drinking water.

This procedure has two disadvantages. In the first place, the factor used to convert ruthenium activity to its equivalent thick source value depends on the exact nature of the fish or seaweed ash and is thus variable. In cases where the activity in the sample is largely due to ruthenium this variation causes a very large uncertainty in the figure for total beta activity excluding Ru106. The second disadvantage is due to the fact that most of the beta emitters in the unidentified group have higher maximum permissible levels in water than 2×10^{-4} microcuries/millilitre, and an appreciable but unknown safety factor is thus introduced.

These disadvantages can be avoided only be carrying out an extensive radiochemical analysis of the samples. It is hoped in future work to obtain averages by bulking samples rather than by averaging results and in this way to reduce the number of samples for analysis to the point where detailed radiochemical analysis becomes feasible.

The maximum permissible levels adopted at Windscale are summarized in Table I.

(To be continued)

References

[1]SELIGMAN, H., "The discharge of radioactive waste products into the Irish Sea, Part I" International Conference on Peaceful Uses of Atomic Energy, Vol. IX. Paper P.418, Geneva, 1955.

[2]DUNSTER, H. J., "The discharge of radioactive waste products into the Irish Sea, Part II." International Conference on Peaceful Uses of Atomic Energy, Vol. IX. Paper P.418, Geneva, 1955.

[3]International Commission on Radiological Protection. Recommendations revised December 1, 1954. *British Journal of Radiology*, Supplement No. 6, 1955.

Table I.—Maximum Permissible Levels of Activity in Marine Materials

Type of activity	M.p.l. in water (μc/ml)	Marine Material	M.p.l. in material (μμc/g)
Total beta	—	Shore sand Shore silt Sea bed	25,000 100,000 100,000
Total alpha (assumed to be Pu239) ..	3×10^{-6}	Fish Seaweed	30 10
Total beta (including or excluding Ru106)	2×10^{-4}	Fish Seaweed	2,000 670
Ruthenium-106	1×10^{-4}	Fish Seaweed	1,000 330
Strontium-90	8×10^{-7}	Fish Seaweed	8 2.7

TEST RIG FOR CANDU

A half million dollar test rig for nuclear reactor components has been completed by Humphreys & Glasgow (Canada), Ltd., at Toronto for the Nuclear Power Plant Division of Atomic Energy of Canada, Ltd.

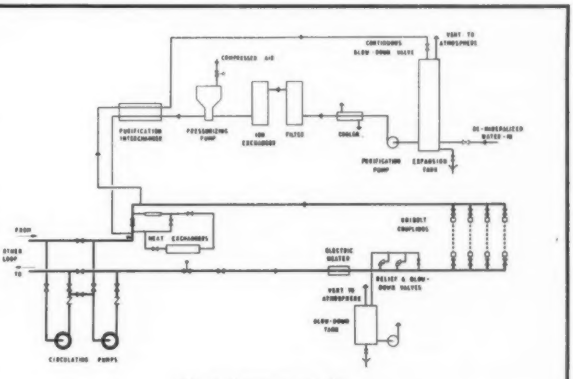
It consists of two test loops, each basically a water-circulating system capable of being operated at the high temperatures and pressures encountered in nuclear reactors. They will be used primarily for testing equipment and components having a direct bearing on the CANDU reactor programme.

The rig is installed at the A. W. Manby Service Centre at Toronto of the Ontario Hydro-Electric Power Commission.

It occupies a ground-floor area of about 5,000 sq.ft. An existing mezzanine floor at 20 ft elevation and a new platform at 8 ft provide service access to the rig. The ends of the loop manifolds on the rig stretch almost 100 ft, while the centre lines of the manifolds run parallel to one another, and for each loop are 28 ft apart.

Two basic types of experiments will be conducted on the rig.

In one, heat will be produced at a constant rate in an experimental test section to study heat transfer characteristics of the heating element. The temperature of the circulating water will be regulated by "dumping" heat in excess of that generated and then controlled by an electric heater, external to the test section.



Flow diagram of rig

The second type of experiment involves no heat input from the test section and the temperature of the water will again be controlled by over-cooling the rig and operating the electric heater on automatic temperature control.

The rig was commissioned and in use only eight months after commencement of design.

DURING my recent visit to Provence I was told by the local people that the long spell of sunny, rainless weather would mean that the vineyards would produce a rich luscious, and almost syrupy wine, as the sugar content of the grapes would be very high. Yet, in this season of sweet grapes, those of the sour taste do not appear to be lacking. So sour, in fact, are some of the grapes lately that good taste might be said to be completely lacking. I am thinking of those opinions, verging on imbecility, which have greeted the Russian moon-hit. At least one writer considered it would have been more of an achievement had the rocket encircled the moon before landing. Such remarks could have been made only through complete ignorance of the difficulties of scientific progress. Much the same attitude was found at the time of the opening of Calder Hall, and it will again crop up when the Dresden power station starts up.

It must be rather disconcerting, and even disheartening, when scientists and engineers, dedicated to making a good job find themselves against a tirade of nonsensical irresponsibility of this sort. And talking of dedication and devotion, should we not admire, and perhaps applaud, the efforts of those Indians who worked as much as 56 hr at a stretch, without leaving the plant, during the fabrication of the prototype fuel elements for the Canada-India reactor. There must have been many teething troubles, but the atomic fuel fabrication plant at Trombay, near Bombay, is now in regular production. At Trombay also, the first of India's reactors, Apsara (Nymph) has now completed three years of successful operation. For the first time medical isotopes produced in this reactor have been made available to public institutions, including the Defence Science College, Delhi, the J. J. Hospital, Bombay, and the Military Hospital, Poona.

* * *

An ambitious nuclear programme requires an adequate supply of engineers, and in this respect Western Germany has found itself in a bottle-neck. It has been estimated that German needs are for 3,500 diploma engineers and 15,000 H.T.L. engineers each year. At present the annual output is 3,000 and 10,500 in these two categories respectively. Thus, there is a yearly deficit of 500 diploma engineers, and of about 4,500 in the second group. So urgent is the situation that serious consideration is being given to the possibility of greatly increasing the turn-out of women engineers. The Vereinigung von Unternehmerinnen (Society for Women Consulting Engineers) is taking the matter in hand. It certainly looks as if the old order of the three K's, Kinder, Kirche and Kuche, will soon have to modified by the addition of the fourth K, Kernenergie, and that the boiler-suit will replace the apron. In fact, it will become necessary to copy the much-deprecated Soviet example, for in Russia about 40 per cent. of those being trained in technology are women.

* * *

Great satisfaction with Soviet methods is found in Rumania, where, with Russian help, the Institute of Nuclear Physics of the Rumanian People's Academy of

'NUCLEARIST' *writes . . .*

Science has now achieved three years of work. The Director, Horia Hulubei, has described how 100 Rumanian atomic scientists have been trained, and a reactor and a cyclotron have been installed, together with laboratories for the study of nuclear reactions, neutron physics, effects of radiations on solids, radiochemistry, spectroscopy with gamma and other radiations, nuclear magnetism, interference optics, cosmic rays, high energies, and industrial isotopes. In the near future there will be added a 30 MeV electron accelerator and an electrostatic accelerator, radiochemical processing laboratories, and an electronic computing centre. Rumanian nuclear science is certainly making rapid progress.

* * *

Much more sluggish has been New Zealand's atomic debut. Although N.Z. scientists have been trained at Harwell even before 1955, it was not until last year that approval was given for the formation of the Institute of Nuclear Science as part of the DSIR. Now, with the site chosen, building can commence and a 3 MeV accelerator will soon be installed. A 1 MW swimming-pool research reactor, of a type to be selected next year, will be built in 1962-63, for start-up during 1963-64. It is openly stated that equipment must be modest, since financial commitments in this line cannot be allowed to burden a country which prefers to spend its money on a comprehensive social security programme. The New Zealanders, in other words, do not intend to spend for prestige.

* * *

In view of the indisputable need for every possible effort to promote international understanding, it is of some surprise that a question of collaboration between different lands should have caused Professor Carlo Salvetti, Director-General of the Atomic Research Centre at Ispra, Italy, to resign his post. He did this in protest against the decision to place the Centre under international control. While Salvetti's decision proves him a brave man, it is great pity that he felt compelled to express his dissatisfaction of collaborative work between European nations in an action which might suggest that personal ambition was in danger of being subordinated to the common weal. It is to be hoped that his successor, Gianfranco Franco, will have a different outlook.

More likely to ease tension is the exchange between British and Soviet scientists. The Russian experts' visit to the fast breeder reactor at Dounreay must be paralleled by a British visit to the Soviet fast reactor which has recently attained its design capacity of 5 MW.

* * *

Rumour has it that the first large Danish reactor is to be not at Riso after all, but in Greenland. At Mestersvig the lead mines are nearing exhaustion, but a little further south are large molybdenum deposits. For the exploitation of these, much power will be required, and the transport of oil or coal to Greenland is very expensive. The answer may lie in nuclear power. Since at present 95 per cent. of the world's output of molybdenum emanates from the U.S.A., a development such as this would be interesting from many points of view.

The Power of a Heavy Water Reactor During an Emergency Shutdown

by

I. M. El-Ibiary

Cairo University

IN cases of emergency, or abnormal conditions of operation, the generation of power in a nuclear reactor may have to be stopped as quickly as possible. A scram signal is then applied to release one or more of the control rods so as to shut down the reactor in a very short time. Sometimes the speed of shutdown is limited in order to reduce the thermal stresses produced in the reactor structure, and the mechanical shock associated with the rapid movement of the " scram " rods.

In JEEP, the heavy water reactor of JENER at Kjeller, Norway, two cadmium plates suspended between the reactor tank and the graphite reflector are assigned for scram shutdowns. The scram signal cuts the current in an electromagnetic clutch which holds the plates in position. A shock absorber halts the movement of the plates at the end of their travel.

Recording Fast Decay

The fast decay of the thermal neutron flux in the reactor when a scram signal is applied was recorded by means of a high speed " Brush " recorder and related, in time, to the movement of the scram plates.

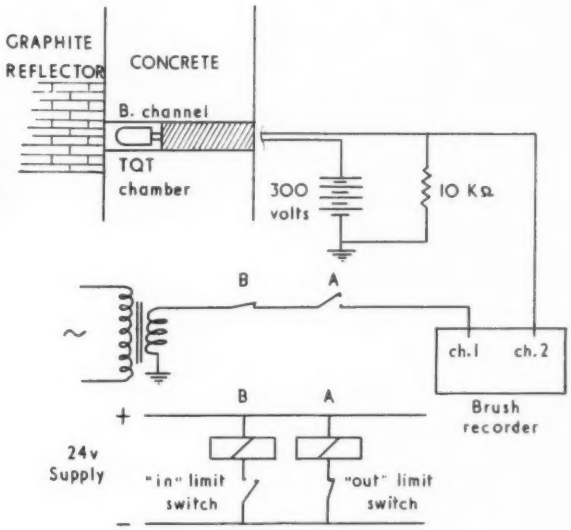


Fig. 1. — Arrangement of equipment for measuring flux decay in actual reactor

This decay curve could, in principle, be obtained, theoretically, by solving a set of simultaneous differential equations which represent the mechanism of neutron production, i.e., the prompt, delayed and photoneutrons and using a suitable function of time to represent the negative reactivity produced by the movement of the scram plates. Such a solution is virtually impossible to obtain analytically. An electronic simulator could be used but it will have to be very large and elaborate, if an exact solution is sought.

Two Solutions

In this article two approximate solutions, applicable over limited periods of time, are presented; one is obtained by means of a simplified reactor simulator and the other is analytical. In both solutions the negative reactivity insertion was assumed to be instantaneous in the form of a step function. For the simulator solution, some of the delayed and photoneutron groups were rearranged into three larger groups and a constant source term, the rest were considered as prompt.

The solutions obtained by the two methods were plotted for different values of negative reactivity. The two sets of curves thus obtained were compared with the experimental curve. The degree of validity of the solutions was thus estimated and the

Summary

To evaluate the shutdown reactivity present in the JEEP reactor at Kjeller, Norway, the fast decay of power when a scram is effected was measured and compared with the solution obtained by an electronic reactor simulator for a step function of negative reactivity, using three groups and a source term to represent the mechanism of delayed neutron production. The experimental curve was compared with the solutions obtained by the simulator for different values of negative reactivity and from the best fit the value of the shutdown reactivity was determined. An approximate analytical solution was also obtained using one group of delayed neutrons and a source term. Such a solution could be used over a limited interval of time and, within this interval, could be relied upon to indicate the value of the shutdown reactivity.

value of negative reactivity which gives the best fit with the experimental curve was determined. This corresponds to the reactivity worth of the scram plates.

The experimental set-up is shown in Fig. 1. Two high-speed relays were used to indicate the times at which the scram plates started and finished their travel. The contacts of the relays connect and disconnect a 50 c/s signal to channel 1 of the " Brush " recorder.

The layout of the circuit used to analyze the reactivity with reactor simulator is shown in Fig. 2.

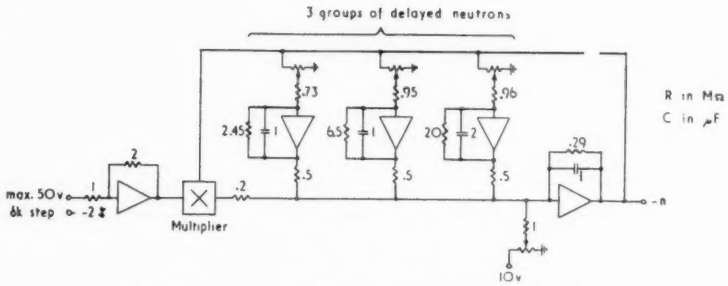


Fig. 2.—Circuit layout for simulator analysis of flux decay

Few Hours Operation

The scram was effected after the reactor had been operating for a few hours at full power. Usually when the reactor is scrammed the control plates move also automatically to the end of their range to assist in the shutdown. This motion is, however, comparatively slow and the negative reactivity thus inserted depends on the position of the control plates during operation. The rate of power shutdown varies therefore according to the position of the control plates, being smallest if they have already been at the end of their range when the scram is applied.

A similar condition was realized in this experiment by switching off the amplidyne circuits of the control plates immediately before effecting the scram, so as to prevent them from moving. The shutdown is then solely due to the movement of the scram plates and corresponds to the rapid insertion of a definite value of negative reactivity.

Temperature No Problem

Temperature effects on the reactivity may, dependent on the initial power level, enter into the picture but within the first minute or so they can be safely neglected.

The measured decay curve is shown in Figs. 3 and 3*a*, the time reference $t=0$ is taken as the instant at which the scram plates started to move and the " out limit " switch was closed (*see* Fig. 1).

The plates took about 1.6 sec to reach the end of their travel but rebounced back and finally came to rest after 3.2 sec from the application of the scram signal.

As shown in Fig. 3, the neutron flux remained almost constant for the first 1.1 sec but afterwards began to fall rapidly. The effect of the rebounce of the scram plates is noticeable, though relatively small.

Decay Continuous

The decay curve does not settle down to a constant negative period. Instead, the period increases continuously even for times as high as

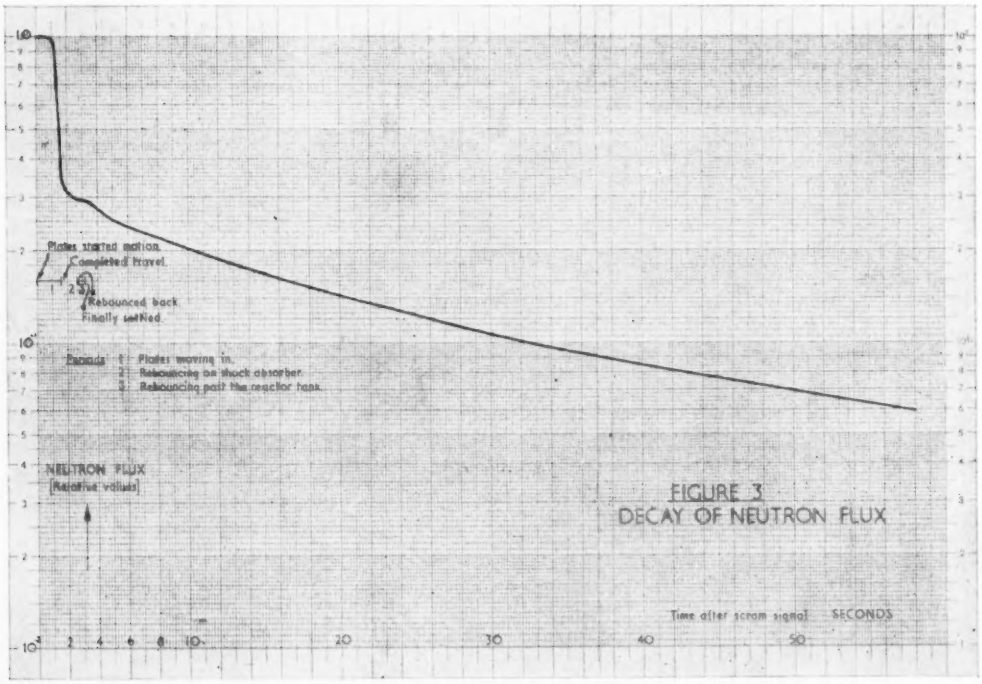


Fig. 3.—Measurement of decay of neutron flux immediately following movement of scram plates

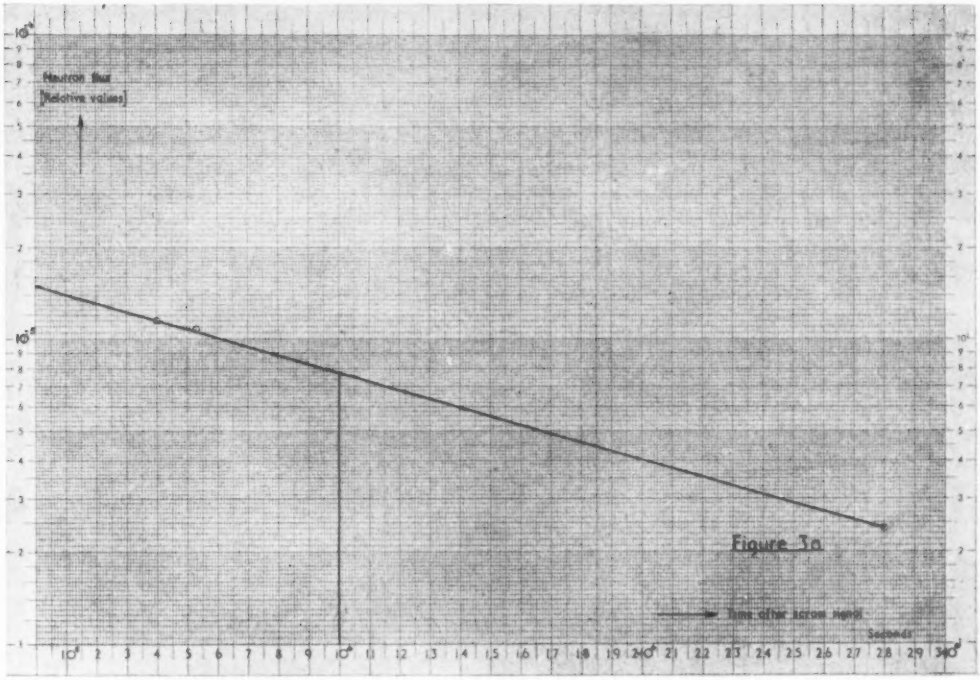


Fig. 3a.—Measurement of decay of neutron flux following emergency shutdown (*continued*)

500 sec. This could only be explained as due to the long-lived photoneutrons (Fig. 3a). The shutdown can be deduced by solving the set of differential equations representing the mechanism of neutron reproduction, namely*:

$$\frac{dn}{dt}=\frac{\delta k-\beta}{l}n+\sum_i \lambda_i C_i \quad . \quad . \quad . \quad \text{(i)}$$

$$\frac{dC_i}{dt}=\frac{\beta_i n}{l}n-\lambda_i C_i \quad . \quad . \quad \text{(ii)}$$

where:

n=number of thermal neutrons/cm^3.

λ_i β_i are respectively the decay constant and yield of the ith group of delayed or photoneutrons.

$\beta=\sum_i \beta_i$.

C_i=concentration of the ith group of delayed or photoneutron precursor.

l=thermal neutron life time in the finite reactor. l is here taken as 2×10^{-3} sec†.

δk=the excess reactivity of the assembly.

*See reference No. 1.
†See reference No. 2.

Strictly speaking, since the plates take a finite time before coming to rest, δk should be inserted in equation (i) as a function of time and this would make the problem extremely difficult to solve. Instead, it was assumed that the change of reactivity is sudden in the form of a step function. This is not as bad an approximation as it might appear at first sight, since the major portion of the negative reactivity is inserted during the short time taken by the plates to move past the "central" part of the reactor tank.

The delayed neutrons from the fission of U-235 form six groups as shown in table I.

Table I.—Delayed Neutron Data*

Group No.	Average life, sec	Yield p.c.m. of total neutrons
1	0.071	25
2	0.62	84
3	2.19	240
4	6.50	210
5	31.7	170
6	80.2	26

The photoneutron production is given by Bernstein *et al*‡ for a point source of fission products in an infinite sphere of heavy water. These results can be used for the case of the reactor, the yield values have then to be reduced to take into account the absorption of photons in the rods and canning. We assume a reduction in yield of about 10 per cent.†**.

Table II gives the nine groups of photoneutrons and their modified yield in p.c.m. of the total neutron production.

Table II.—Photoneutron Data†

Group No.	Average life, sec	Yield p.c.m. of total neutrons
1	3.5	60
2	59	18.8
3	206	6.6
4	667	3.1
5	2,340	1.9
6	8,570	2.2
7	22,860	0.31
8	275,500	0.088
9	1,595,000	0.043

An analytical solution of equations (i) and (ii) in their present form is virtually impossible. Even if an

*See reference No. 1
‡See reference No. 3

†See reference No. 2.
**See reference No. 4.

electronic simulator is available to handle the problem it would have to be fairly large and elaborate. Therefore, some approximations have to be made to simplify the problem, but the resulting solution applies over a limited interval of time only.

Approximate Solution

A simple reactor simulator capable of accommodating three groups of delayed neutrons and a source term was available. This was used to obtain an approximate solution of equations (i) and (ii) which is applicable for the time interval between about 3 sec and 60 sec.

The delayed- and photoneutron groups were arranged as follows:

(*a*) Groups 1 and 2 of the delayed neutrons, in view of their short average lives, were considered as prompt.

(*b*) Group 3 of the delayed neutrons (average life 2.19 sec), was added to the first group of photoneutrons, of average life 3.5 sec, to form one single group I, whose yield is: $0.240+0.060=0.30$ per cent., and whose average life is: $(0.240\times 2.19+0.060\times 3.5)/0.3=2.45$ sec.

(*c*) Group 4 of the delayed neutrons, average life 6.5 sec, was considered on its own to form group II.

(*d*) Group 5 and 6 of the delayed neutrons and group 2 of the photoneutrons were added together to form a new group III, whose yield is: $0.170+0.026+0.019=0.215$ per cent., and whose average life is:

$$\frac{(0.170\times 31.7+0.026\times 80.2+0.019\times 59)}{0.215}$$

$=40$ sec.

(*e*) Groups 3, 4,...9 of the photoneutrons were considered as a constant source term producing 14.2×10^{-5} of the total number of neutrons produced before the shutdown. The rearranged groups are shown in Table III.

Table III.—Rearranged Delayed Neutron Data

Group No.	Average life, sec	Yield p.c.m. of total neutrons
I	2.45	300
II	6.50	210
III	40	215
S	∞	14.2

The problem was then in this form set on the simulator, see Fig. 2, and solutions were obtained for different values of δk. These are shown in Fig. 4, together with the experimental curve. It is seen that the experimental curve would fit fairly well to the curve corresponding to $\triangle k\approx 1.24$ per cent., except for times less than 8 sec.

The reactivity worth of the two scram plates is therefore approximately 1.24 per cent.

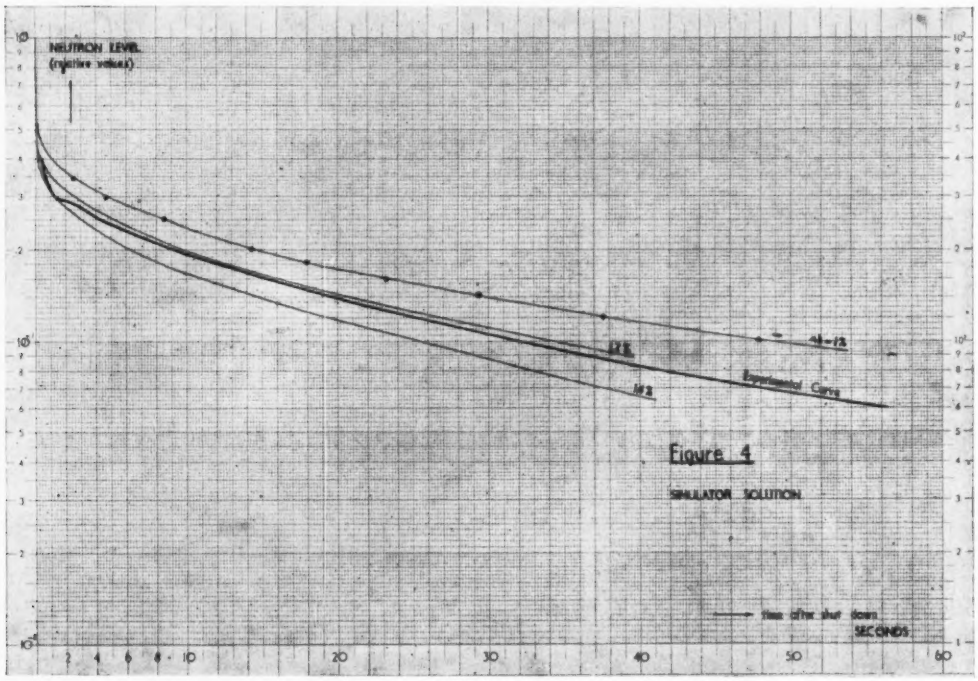


Fig. 4.—Graph obtained from measurements made on simulator with different reactivity values

The analytical solution of equations (i) and (ii) involve the solution of an algebraic equation of the order $(S+I)$ where S is the number of groups used. For more than one group of delayed neutrons, the solution becomes quite difficult to obtain or use.

For the problem in hand, an analytical solution applicable for the time interval between about 3 sec and 10 sec was obtained using one delayed neutron group and a source term as follows:

(*a*) Again groups 1 and 2 of the delayed neutrons were considered as prompt.

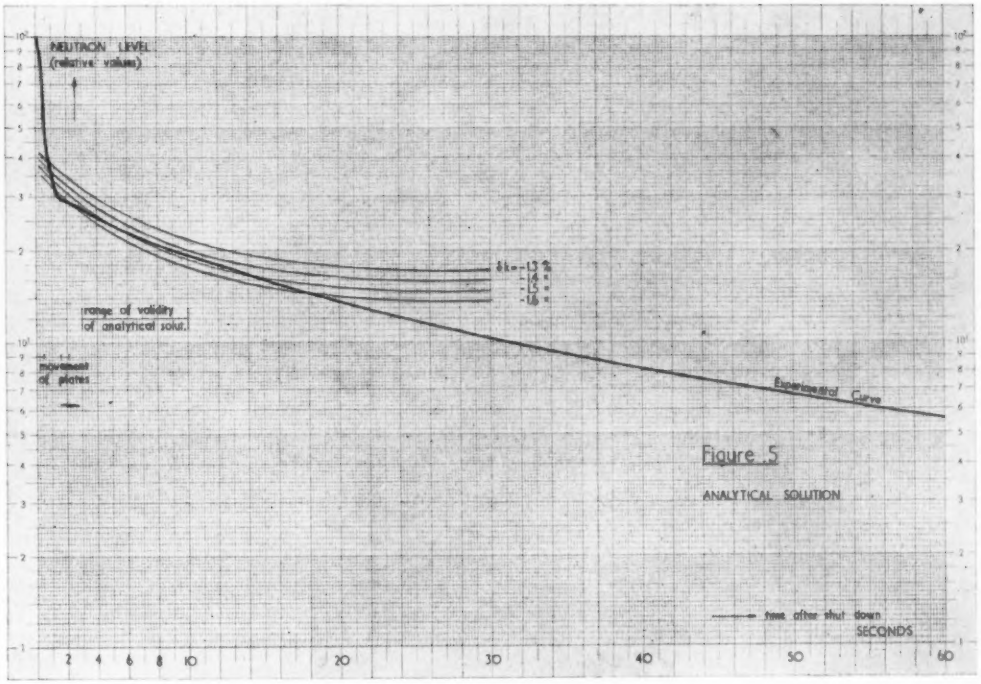


Fig. 5.—Graph obtained from solution of equation (v) for different values of reactivity

(*b*) Groups 3 and 4 of the delayed neutrons and group 1 of the photoneutrons were added together to form one group whose yield is: $0.240 + 0.210 + 0.060 = 0.510$ per cent., and whose average life is: $(0.240 \times 2.19 + 0.210 \times 6.5 + 0.060 \times 3.5)/0.51 = 4.1$ sec.

(*c*) The remainder of the delayed- and photoneutrons were considered as a constant source producing 0.229 per cent. of the total neutron production before the shutdown.

The equations (i) and (ii) then become:

$$\frac{dn}{dt} = \frac{\delta k - \beta}{l} n + \lambda C + S \quad . \quad .(iii)$$

$$\frac{dC}{dt} = \frac{\beta}{l} n - \lambda C \quad . \quad . \quad . \quad .(iv)$$

where S in the contribution of the source term equals $\frac{a n_o}{l}$ where n_o is the neutron density before shutdown and $a = 0.229$ per cent.

It is seen from equation (iii) that, for the steady state operation, the reactor assembly must be subcritical by an amount equivalent to the source strength influence, i.e., by 0.229 per cent.

The solution of equations (iii) and (iv) is:

$$\frac{n}{n_o} = \frac{(a+\delta k)(\lambda l+\beta)(\lambda l+\beta-\delta k)}{\delta k[\delta k l\lambda+(l\lambda+\beta-\delta k)^2]} e^{\frac{\lambda \delta k}{\lambda l+\beta-\delta k} t} +$$

$$\frac{(a+\delta k)(\beta-\delta k)}{\delta k l\lambda+(l\lambda+\beta-\delta k)^2} e^{-\frac{\lambda l-\delta k+\beta}{l} t} - \frac{a}{\delta k} \quad . \quad . \quad . \quad . \quad . \quad (v)$$

Equation (v) is plotted for various values of δk and the resulting curves are shown in Fig. 5. It is seen that even in the limited interval between 3 sec and 10 sec, the experimental curve does not fit any of the calculated curves. This is mainly due to the approximation involved in lumping together the 2.19 sec and 6.50 sec groups of the delayed neutrons.

The best fit with the experimental curve, over the 3 sec to 10 sec interval, is for value of $\delta k \approx 1.48$ per cent. The reactivity worth of the scram plates is $(\delta k - a)$ and equals $1.48 - 0.229 = 1.25$ per cent.

The agreement between the values obtained in both solutions is as good as could be expected regarding the approximations used in both methods. Taking into account the inaccuracy in the used values of β_i and l, one can assume the shutdown reactivity of the two scram plates to be: 1.2 ± 0.2 per cent.

The author wishes to thank Mr. K. P. Lien for his generous assistance at various stages during this work, and Mr. B. Winther for providing the simulator solution.

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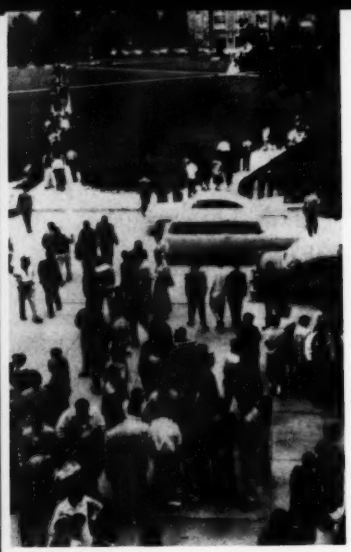
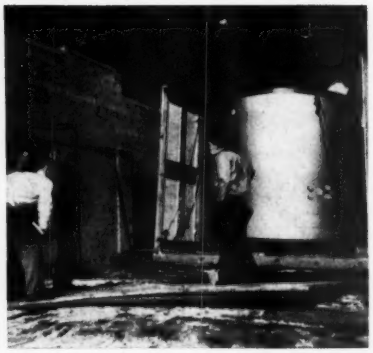


"Wild West" University Installs Reactor

L-77 for Wyoming

An additional teaching and research facility has been acquired by the University of Wyoming, Laramie, in the form of a nuclear reactor. It is a 10 watt aqueous homogeneous reactor, the L-77, manufactured by Atomics International, a division of North American Aviation, Inc. It will be used primarily for graduate work in reactor engineering and technology, radiation chemistry and reactor physics. It will also be used for producing radioisotopes for research by the Schools of Agriculture, Pharmacy, and Arts and Sciences, the College of Engineering and the Natural Resources Research Institute

The overall size of the L-77 reactor is 8 ft high by 8 ft diameter and it can be conveniently accommodated on the back of a lorry for shipping purposes. The arrival of Wyoming University's reactor (*above and right*) causes speculation amongst onlooking students. It is thought at Wyoming that eventually all engineering students, regardless of their ultimate specialities, will have to study nuclear engineering. The reactor will thus be kept busy



(*Below*) An Atomics International engineering student installs the control rod and drive of the Wyoming University's reactor. Two of the teaching staff look on. The reactor is installed in the university's engineering department

The aqueous homogeneous reactor is specially suited for use in universities because of its inherent safety. The large negative temperature and power coefficients of reactivity provide an effective shutdown mechanism should an otherwise uncontrolled power excursion develop. Fuel costs are kept to a minimum and fuel additions can be made in any predetermined amounts safely and easily. Cost of the reactor is low and requires a relatively low operating staff for it to be maintained safely. (*Below*) The uranyl sulphate solution used as fuel is transported in special containers

Senator Gale McGee is briefed before he starts the reactor up at a special ceremony

L-77—The Aqueous Homogeneous Reactor Supplied to Wyoming University

AQUEOUS homogeneous reactors are unique in the huge family of reactors in that one fluid is used as fuel, moderator and coolant. Fissile and fertile materials are dispersed in either light or heavy water as either a solute or slurry. Such reactors can be used for the production of power, fissionable materials and neutrons.

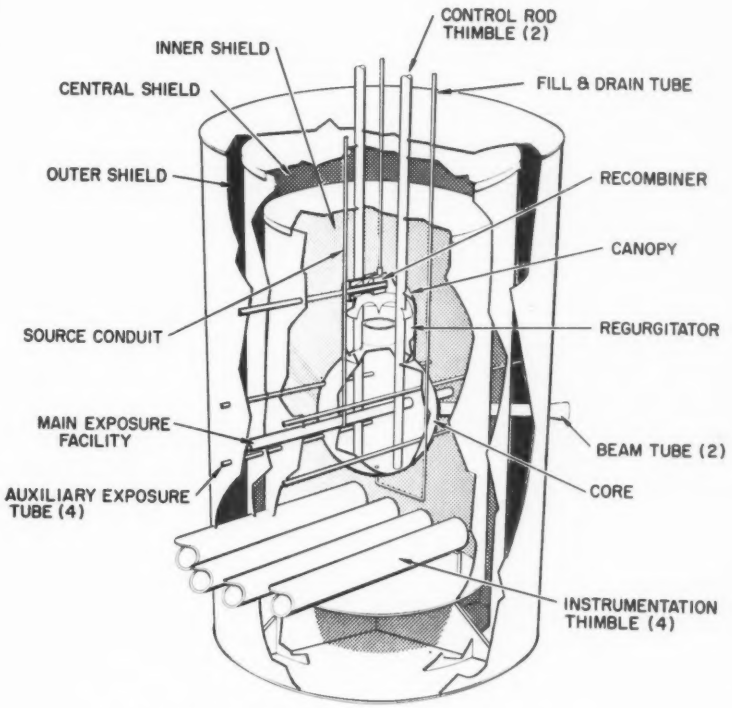
Reactor Advantages

The attractive features of the aqueous homogeneous reactor are: fuel handling and processing are simplified: continuous purification of the fuel is possible; the large negative temperature coefficient provides a high degree of stability; control by adjustment of fuel can be substituted for control by mechanical means; neutron economy is improved by the elimination of most structural materials from the core region; and, finally, by proper selection of the fuel compounds parasitic absorption by the fuel can be made negligible.

The first reactor of the aqueous homogeneous type was built in 1944 at the Los Alamos Research Laboratories. Following its safe and favourable operation, Atomics International a division of North American Aviation, Inc., decided in 1948 to develop this reactor type. Since then they have designed, built and supplied to various organizations, both in the States and overseas, a number of " solution " type reactors.

Training Facility

The Laboratory Reactor, or L-77, as recently supplied to the University of Wyoming, Laramie, is specifically designed for use in educational establishments and research laboratories. It has a low power output—10 kW—and can be used for the production of a wide and useful range of radioisotopes, as well as for studies in basic radiation, nuclear physics and reactor technology. It also serves as a training facility for potential users and operators of power reactors.



Sectional drawing of the L-77 research and training reactor

Because of its size the L-77 can be transported and installed in an existing laboratory at little expense. The unit requires only one operator and the arrangement of equipment is such that all observations can be made by the operator at the control desk. Maintenance requirements are small.

The core of the L-77 consists of a stainless steel sphere containing a solution of uranyl sulphate enriched to 20 per cent. or more in U-235. The core is surrounded by a three-region primary shield which also acts as the reflector.

Water Additional Shield

The core and its primary shield are contained in a tank of water, the tank measuring approximately 8 ft in diameter and 7 ft in height. The water acts as an additional shielding.

A canopy on the spherical core provides both a recombination chamber for radiolytically dissociated gases and overflow chamber for the fuel. Two cadmium cylinders moving vertically and passing through the sphere act as safety rods.

A fuel-solution mixing bowl can be temporarily attached to the outside of the water tank and connected to the bottom of the sphere by means of a small tube.

There are one main exposure tube and four smaller diameter tubes running from the core for experimental work, and two beam tubes, one for gamma ray exposures and the other for neutron production.

The design power level of the reactor is 10 kW. The maximum neutron flux is slightly more than 2×10^8 n/cm²/sec. Gamma ray intensity at core centre is 2×10^3 R/hr.

DRESDEN GOES CRITICAL

World's First BWR Power Station

The Dresden reactor plant nearing completion

Six months ahead of schedule, the Dresden nuclear power station situated some 50 miles southwest of Chicago, recently went critical. Designed to have an output of 180 MW, Dresden is the largest full-scale nuclear power station to be completed in America. It is also the first large scale boiling water reactor plant to be based on the boiling water reactor concept. This is the reactor type which is displacing the pressurized water reactor as a suitable unit for large scale power stations. So great is the confidence of its designers and of the operators of experimental units, there is a possibility that The United Kingdom Atomic Energy Authority will build a BWR. Dresden has been built for the Nuclear Power Group Inc. by General Electric of America

THE Dresden nuclear power station is located approximately 50 miles south-west of Chicago on a 960-acre site at the confluence of the Kankakee and Des Plaines rivers. The property is roughly one mile wide by one-and-a half miles long. It is gently rolling and easily drained. Prior to acquisition of the property by the Commonwealth Edison Co., owners of the plant, it was utilized for farming and grazing, and, during and after construction, portions of the land outside the plant limits will continue to be used for these purposes.

The nearest concentration of population is the township of Morris, approximately eight miles to the west. The nearest city of size is Joliet, about 20 miles to the north-east. The plant itself is so located that it is half a mile from any off-site land and provision is made for the addition of three more units also located within the half-mile radius criterion. Bedrock underlies the general plant area within 4 ft of the ground surface.

The rock formation consists of a 23 ft layer of sandstone, 20 ft of limestone, 71 ft of shale and 268 ft of dolomite. Approximately 150,000 cu.yd of rock excavation was required.

Dual Cycle Steam

The reactor system selected for the station design is the forced circulation, dual cycle, light water cooled and moderated type. In the dual cycle reactor, energy is removed from the reactor core directly by steam which flows to the primary turbine control valves and indirectly by extracting heat through a heat exchanger from the reactor recirculating water to produce steam at a lower pressure. The lower pressure steam flows to the turbine through the secondary turbine control valves.

The primary and secondary steam passes through a conventional turbine cycle with a condenser, feed pumps, and extraction feedwater heaters and then is returned to the primary steam drum and the secondary steam generators. The pressure in the reactor is held constant by the primary turbine control valves. The fraction of the total energy removed through the secondary or low pressure system controls the temperature of the water returning to the reactor, which, in turn, determines the reactor output.

A brief summary of the overall plant performance at rated load follows:—

Gross generator output	192,000 kW
Net station electrical output	180,000 kW
Reactor power output	626,000 kW
Net plant heat rate ..	11,880 B.t.u./kWh
Reactor pressure ..	1,015 lb/sq.in. abs.
Secondary steam generator pressure ..	510 lb/sq.in. abs.
Turbine back pressure	2½ in. Hg abs.
Feedwater temperature	405° F.

The overall plant consists of a reactor plant enclosed in a spherical steel structure, a turbine-generator building, fuel handling and storage facility, administration and access control building, radioactive waste handling facility, circulating water intake and discharge canals, switchyard, ventilation stack, and supporting facilities such as a machine shop and a warehouse.

Sphere Dominates

The dominant physical structures of the plant are the reactor enclosure and the turbine building. The enclosure is a steel sphere, 190 ft in diameter with approximately 40 ft of

its height below grade. The enclosure is constructed of 3,500 tons of plate, ranging in thickness from 1¼ in. at the top to 1.4 in. near grade.

The enclosure is designed to withstand internal pressure of 29½ lb/sq.in. gauge, and has been tested with air to 37 lb/sq.in. gauge. A leakage rate determination test was performed at design pressure and the leakage was found to be negligible.

Access Air Locks

Access to the enclosure is provided by three pressure locks. An 8 ft × 8 ft equipment lock permits removal of equipment from the enclosure to the turbine building where it is then handled by a 100-ton crane. A normal personnel lock, 2 ft 6 in. × 6 ft and an emergency escape lock 30 in. in diameter are also provided. A 16 ft diameter bolted opening is provided for handling equipment in and out of the enclosure during shutdown periods.

The turbine building is located immediately adjacent to and west of the containment vessel. This is a structural steel frame building 200 ft long, 90 ft wide and 90 ft high. The upper portion of the building is enclosed with corrugated asbestos cement siding and the lower portion on the west end of the building is enclosed with aluminium insulated panel.

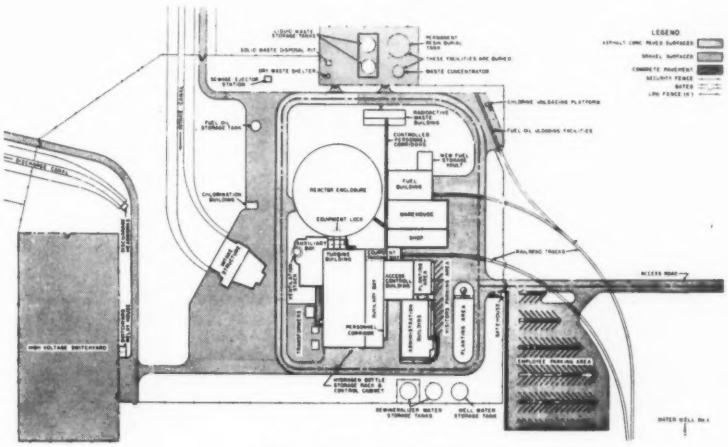
Along the south edge of the building is an auxiliary bay which houses plant service facilities, such as air compressors, water treatment and air conditioning equipment. Two plant heating boilers are located in another auxiliary bay on the north side of the turbine building. Ranging along the south of the turbine building and spherical enclosure are the administration building and access control building, shop, warehouse and fuel buildings. Radiation waste treatment and storage facilities are located east of the sphere. These service buildings are also structural steel frame buildings enclosed in either aluminium panel or corrugated asbestos cement siding.

Main Power Plant

The main power equipment is housed in the reactor enclosure and turbine building. The reactor plant equipment consisting of the reactor, reactor recirculating system, interconnecting piping, associated auxiliaries and necessary shielding are installed in the enclosure.

The reactor recirculating system consists of the reactor, steam drum, four recirculating pumps, four secondary steam generators, and the interconnecting piping. Each of the four pump-steam generator units is placed in a shielded cell and suitably equipped with valves so that the individual units may be taken out of service and maintained while the remainder of the plant is in operation.

The main power conversion equipment and auxiliaries are installed in the turbine building. In a group of compartments shielded by concrete walls are the turbine-generator, condenser, feedwater heaters, air ejectors, condensate pumps, secondary feed pumps, condensate demineralizers and radioactive process piping. The feedwater heaters, turbine-generator, and railroad spur are served by a 100-ton overhead bridge crane which is provided with adequate pendant and cab controls.



Layout of the Dresden site

Control Room

An extension of the main turbine building provides a laydown area on the turbine floor. On an intermediate floor directly below the laydown area is the control room, auxiliary instrument room and switchgear. Battery rooms, the two exciters, switchgear and instrument shop are located on the ground floor. The primary feed pumps make-up water treating equipment and other items are installed in the auxiliary bay.

Materials used in conventional power plant construction are used to the greatest possible extent. Carbon steel is used throughout the main steam and condensate system with a few exceptions. In general, the turbine metals are conventional materials for the rated steam and temperature pressure. Alloys of higher chromium content, however, are used in areas which are most susceptible to erosion and corrosion.

Monel tubes are used in the three high pressure stages of feedwater heating to provide adequate corrosion resistance. Tubes in the two lower pressure stages are copper-nickel. In general, stainless materials are used on all surfaces in contact with the primary fluid during operation. The stainless surfaces are provided by using type-304 stainless steel or carbon steel base materials clad with 304 stainless steel.

The reactor vessel contains the reactor core, the core supporting structures, the control rods, and the ruptured fuel element locating system. It is a cylindrical pressure vessel approximately 40 ft 6 in. high and 12 ft 2 in. inside diameter with a design pressure of 1,250 lb/sq.in. gauge.

The head closure is bolted with a metal "O" ring seal. Water from the secondary steam generators enters the lower portion of the vessel through four 22 in. openings. The steam-water mixture from the core leaves the vessel through twelve 16 in. openings. Other openings are provided for instrumentation, venting, and for recirculating cooling water through the core during shutdown.

The vessel is fabricated of ordinary carbon steel with molybdenum, clad

with type-304 stainless steel. The vessel shell is 5½ in. thick and the approximate weight is 350 tons.

The steam drum contains devices for separating the steam-water mixture from the reactor vessel, devices for drying the steam delivered to the turbine-generator, and a water storage volume of 1,500 cu.ft. The materials and the design pressure are identical to those used in the reactor vessel design. The drum is supported by constant support hangers allowing it to move with the thermal expansion and contraction of the reactory system piping. Under rated conditions, the steam drum delivers 1,405,000 lb/hr of steam at 990 lb/sq.in. abs. to the turbine-generator at a steam quality of 99.9 per cent.

Boiling System

The four secondary steam generators each consist of a vertical shell with a U-tube bundle in the lower part of the shell carrying the reactor system water. Heat extracted from the reactor system water boils water in the steam generator shell which also contains steam separating and drying devices. The reactor system water enters and leaves the tube bundle through two 18 in. nozzles in the lower head of the steam generator. The steam leaves through a 12 in. nozzle in the steam generator shell.

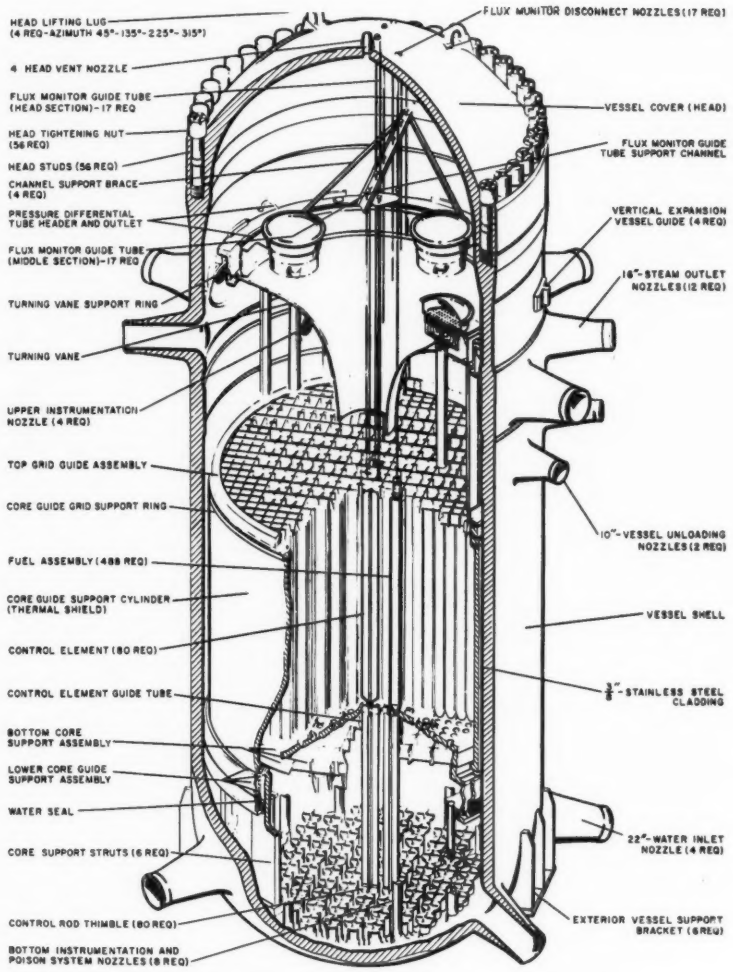
Feedwater is injected into the shell through a three-element feedwater control system. Under rated conditions, each steam generator delivers 297,800 lb/hr of steam at 510 lb/sq.in. abs. to the turbine-generator. The steam generator shell and tube bundle are designed for a pressure of 1,250 lb/sq.in. gauge.

Pumping Systems

There are four pumps to recirculate water from the steam drum through the secondary steam generators back to the reactor vessel. One pump is associated with each steam generator. These pumps are of the vertical centrifugal type with closely coupled canned motors. This design eliminates any possibility of shaft packing leakage. Each pump is designed to deliver 16,500 gal/min with a developed head of 103 ft. The motor is rated at 600 h.p. The pump and motor casing are designed for a pressure of 1,250 lb/sq.in. gauge.

The main circulating piping is fabricated from type-304 stainless steel. The risers from the reactor vessel to the drum and the downcomers from the drum to the headers for the recirculating pumps are 16 in. o.d., the recirculating pumps suction headers are 22 in. o.d., and the lines directing the fluid from the pumps to the steam generators and return to the reactor vessel are 18 in. o.d. Wall thickness of this pipe corresponds approximately to pipe schedule 100. The piping is supported by constant support hangers to permit thermal movement.

Valves in the main circulating lines are similar to conventional gate valves except that they are made from type-304 stainless steel castings and forgings and are provided with a double set of stem packing with a leak-off between the two sets to a safe location. All valves are electric-motor-operated.


HEAD LIFTING LUG (4 REQ-AZIMUTH 45°-135°-225°-315°)
4 HEAD VENT NOZZLE
FLUX MONITOR GUIDE TUBE (HEAD SECTION)-17 REQ
HEAD TIGHTENING NUT (56 REQ)
HEAD STUDS (56 REQ)
CHANNEL SUPPORT BRACE (4 REQ)
PRESSURE DIFFERENTIAL TUBE HEADER AND OUTLET
FLUX MONITOR GUIDE TUBE (MIDDLE SECTION)-17 REQ
TURNING VANE SUPPORT RING
TURNING VANE
UPPER INSTRUMENTATION NOZZLE (4 REQ)
TOP GRID GUIDE ASSEMBLY
CORE GUIDE GRID SUPPORT RING
FUEL ASSEMBLY (488 REQ)
CORE GUIDE SUPPORT CYLINDER (THERMAL SHIELD)
CONTROL ELEMENT (80 REQ)
CONTROL ELEMENT GUIDE TUBE
BOTTOM CORE SUPPORT ASSEMBLY
LOWER CORE GUIDE SUPPORT ASSEMBLY
WATER SEAL
CORE SUPPORT STRUTS (6 REQ)
CONTROL ROD THIMBLE (80 REQ)
BOTTOM INSTRUMENTATION AND POISON SYSTEM NOZZLES (8 REQ)
FLUX MONITOR DISCONNECT NOZZLES (17 REQ)
VESSEL COVER (HEAD)
FLUX MONITOR GUIDE TUBE SUPPORT CHANNEL
VERTICAL EXPANSION VESSEL GUIDE (4 REQ)
16"-STEAM OUTLET NOZZLES (12 REQ)
10"-VESSEL UNLOADING NOZZLES (2 REQ)
VESSEL SHELL
⅜"-STAINLESS STEEL CLADDING
22"-WATER INLET NOZZLE (4 REQ)
EXTERIOR VESSEL SUPPORT BRACKET (6 REQ)

Isometric view of the reactor core and pressure vessel assembly

There are 80 control rods in the reactor core, each with an individual drive mechanism. Each drive mechanism is housed in a 4 in. i.d. thimble attached to and extending below the reactor vessel.

Hydraulic Drives

The drive mechanisms are hydraulically operated using reactor feedwater as a hydraulic fluid. The principle of positioning these control elements is that of a piston driven by an unbalanced force. Insertion movement requires no unlocking of latches but withdrawal movements require an unlocking of the latch by water pressure. As hydraulic system pressure is always higher than reactor pressure, drive mechanism leakage is always into the reactor. Each drive mechanism is operated independently

and the system control is so interlocked that only one control rod can be moved at a time.

For emergency insertion of all rods (reactor scram) there is a hydraulic accumulator for each three drive mechanisms. The accumulator is charged with feedwater to 1,400 lb/sq.in. A shuttle valve will expose the lower side of the piston to reactor pressure in the event that accumulator pressure is for any reason lower than reactor pressure. The balance of forces with reactor pressure on the drive mechanism is sufficient to complete the scram from the initiation of a scram signal to full insertion of all control rods in approximately 3 sec.

If for any reason the steam flow to the turbine-generator or the main condenser is interrupted an emergency condenser is provided to remove the decay heat from the reactor core. This emergency condenser consists of a tank 42 ft long and 14 ft in diameter located above the steam drum, within the reactor enclosure. Two separate tube bundles connected to the steam drum are inserted in the lower portion of the tank. The tank is filled with water and is vented to the atmosphere outside the enclosure. When the emergency condenser is required, a normally closed valve in the drain line from each tube bundle opens, and the emergency condenser operates by the natural circulation of steam from the steam drum to the tube bundles where it is condensed and drains by gravity back to the drum. The water in the tank is heated and boils off to atmosphere. The tank holds 30,000 gal of water, sufficient to last a minimum of eight hours without replenishment.

Shutdown Cooling

The shutdown cooling system consists of two pumps and two heat exchangers operating in parallel. The system takes water from nozzles on the side of the reactor vessel, circulates it through the heat exchangers and discharges the cooled water into the main circulating lines returning to the vessel. The primary use of the system is to cool the reactor system down and remove the decay heat from the reactor core when it is necessary to remove the vessel head for refuelling or repairs.

The emergency poison system consists of a 300-gal tank filled with a sodium pentaborate solution located above the steam drum. Connections are made to the tank from the steam drum and from the lower portion of the reactor vessel such that when the valves in the connecting lines are opened, the boron solution will drain by gravity into the reactor vessel. This system is provided as an emergency method of shutting down the reactor in the unlikely event of failure of an excessive number of control rod drives. There is sufficient boron in this system to poison the reactor core below criticality under any circumstances.

The core of the reactor occupies an approximate cylindrical space 9.9 ft high and 10.7 ft circumscribed-circular diameter. It contains 488 fuel assemblies. Each fuel assembly consists of a 4.29 in. square Zircaloy-2 channel in which are arranged 36 fuel rods in a square array.

The fuel assemblies are supported by a bottom core support plate which in turn is supported by a ring girder attached to columns rising from the bottom of the vessel. A thermal shield surrounding the core rests on the ring girder and supports an upper grid guide assembly. Thus, the fuel assemblies rest on the bottom core support plate and are held in transverse alignment by the upper grid guide assembly.

Eighty cruciform control rods enter the bottom of the core through holes in the core support plate. These rods pass between fuel assemblies and are guided by the channels of the fuel assemblies.

Fuel Details

As described above, each fuel assembly consists of 36 fuel rods contained in a square Zircaloy-2 channel. Each rod consists of four segments of Zircaloy-2 tubing with an outside diameter of 0.56 in. and a wall thickness of 0.030 in. Each segment is filled with sintered pellets of slightly enriched uranium dioxide. Each pellet is 0.500 in. long and 0.494 in. in diameter. The ends of each segment are plugged and the four segments are screwed together to form a fuel rod. The active length of each fuel rod is 105.2 in.

Tie plates are attached at either end of each fuel assembly to hold the rods in place. Spacer plates are affixed to the rods at each of the three segment junctions to prevent bowing of the fuel rods. A lifting bail is attached to the upper tie plate for handling the assembly. A nose piece is attached to the lower tie plate, fits into a hole in the bottom core support plate and contains an orifice for adjusting the water flow through the assembly. The tie plates, the lifting bail, and the nose piece are all made of type-304 stainless steel.

(*To be continued*)

Principal Design Parameters of Dresden

Core Assembly	
Diameter (maximum o.d.)	10.7 ft
Height (fuel assembly)	9.9 ft
Lattice pitch	0.71 in.
Channel diameter	4.29 in.
Fuel rods/channel	36
Number of fuel assemblies	488
Fuel rods in reactor	17,551
Water volume to UO_2 volume	2.17:1
Fuel	
Rod construction	UO_2 pellets in Zr jacket
Rod length	117 in.
Active rod length (hot)	105.2 in.
Rod diameter (o.d.)	0.56 in.
Uranium in reactor	58 tons
Enrichment	1.5 per cent.
Irradiation time (70 per cent. operation; 10,000 MWD/ton)	4 years
Uranium throughput	31,980 lb/year
Maximum neutron flux	5×10^{13} n/sq.cm/sec
Total reactivity required (at start of equilibrium loading period)	11.6 per cent.
Heat Transfer and Fluid Flow (Rated Load)	
Average heat flux	94,660 B.t.u./hr/sq.ft
Maximum heat flux (hot spot)	346,000 B.t.u./hr/sq.ft
Average power density (in-core coolant volume)	1,390 kW/sq.ft
Maximum fuel temperature (centre)	4,570°F.
Inlet water velocity (centre channel)	6.44 ft/sec
Exit water velocity (centre channel)	12.46 ft/sec
Average steam quality (by weight)	4.92 per cent.
Average steam quality (by volume)	44.5 per cent.

PEOPLE... in the NUCLEAR NEWS

MR. S. SCOTT, OBE, MA, chief personnel officer of the Central Electricity Generating Board, has retired. He is succeeded by **MR. HAROLD C. SPEAR,** formerly chief personnel officer to the British Overseas Airways Corporation. Mr. Scott will continue for some months as adviser on labour relations.

Leaving the U.K. Atomic Energy Authority to enter industry is **MR. JOHN DOLPHIN,** CBE, TD, DLC, FInstF, engineer-in-charge of the research group. He has been appointed joint managing director of Lansing Bagnall, Ltd., manufacturers of handling equipment. An engineer with many inventions to his credit, Mr. Dolphin was during the war commanding officer of the inter-services research

Mr. John Dolphin

establishment. In this capacity he was responsible for the design and development of two types of a midget submarine and of a parachutist folding motorcycle, the forerunner of present-day motor scooters. After leaving the services he set up his own consultancy and design business but later joined the Ministry of Supply's atomic energy division. Later, with the Atomic Energy Authority, he worked at Aldermaston and was latterly responsible for the construction of the Atomic Energy Establishment, Winfrith.

To promote the study of nuclear physics, the University of Stellenbosch, South Africa, has created a professorship in nuclear physics. The first holder will be **DR. W. E. FRAHN,** research officer in the department of nuclear physics of the National Physics Laboratory, Pretoria. A graduate of the Aachen Technical University, Germany, he was appointed to the South African Council for Scientific and Industrial Research at Pretoria in 1955. He attended the Second International Conference on the Peaceful Uses of Atomic Energy in Geneva last year.

DR. NORMAN LOVELESS, who is a lecturer in psychology at Queen's College, Dundee, has been appointed as a consultant to Smiths Aircraft Instruments, Ltd. The growing application of experimental psychology to equipment design has from the first been closely associated with the problems of aircraft instrumentation, since it was recognized during the last war that the pilot's ability to respond quickly and accurately to the information with which he was presented could be improved by scientific study of his capacities and limitations. With the increasing speed of modern aircraft, this task has become still more urgent. Dr. Loveless has been engaged for some time in research in this field, and will advise Smiths in the light of the considerable body of knowledge which has been built up over the past 15 years.

Recently returned to his regular work at the Argonne National Laboratory, Lemont, Illinois, after completing the task of editing the 33-volume *Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy* is **MR. JOHN H. MARTENS.** Engaged in the Argonne Technical Information Division, he started preparatory work on the editing in April, 1958, five months before the conference started. At first he was stationed in New York, then, in July, he transferred with his staff to Geneva, where he remained until March, 1959. Before returning to New York he organized an editorial office in London. Among the team of scientific editors who helped Mr. Martens were three other Argonne staff members. The team was made up of from five to 24 scientists representing six countries. A graduate of Bradley University, Peoria, Illinois, Mr. Martens was a research assistant in the University of Chicago Metallurgical Laboratory, predecessor to Argonne. He was later assigned to the Westinghouse Research Laboratory to assist in the manufacture of uranium metal for the first atomic pile. In the Army he worked in the operations office at the Y-12 uranium plant in Oak Ridge, Tennessee. Afterwards he worked with the Manhattan District on assignments at Bikini Atoll and Oak Ridge. In 1948 Mr. Martens was transferred to Washington where he worked in the U.S. Atomic Energy Commission Information Service until September, 1955, when he joined the Argonne.

To further their studies on the fundamental structure and properties of the basic question of what is the nature of matter, the Argonne National Laboratory, Lemont, Illinois, have formed two new scientific divisions—high energy physics and solid state science. Acting director of the high energy physics division will be **DR. ROGER HILDEBRAND,** who is also associate laboratory director for high energy physics. Director of the solid state science division will be **DR. OLIVER C. SIMPSON** formerly associate director of the laboratory's chemistry division. Coinciding with Dr. Simpson's appointment, **DR. DONALD C. STEWART** has been named associate director of the chemistry division. Dr. Hildebrand assumed the newly created post of associate laboratory director for high energy physics when he joined Argonne in September, 1958. He came to Argonne from the University of Chicago where he was an associate professor of physics in the department of physics and in the Enrico Fermi Institute for Nuclear Studies. He continues to hold these appointments. During his six years as a full-time staff member of Chicago University, Dr. Hildebrand studied the properties and characteristics of the meson, one of the sub-atomic particles made in particle accelerators. His meson research was conducted with the aid of the university's synchrocyclotron. Dr. Simpson joined the chemistry division of the metallurgical laboratory of Chicago University (forerunner of Argonne) in 1944 as an authority in high vacuum experimental techniques. There he assumed charge of a research team determining the high temperature properties of plutonium and its compounds in connection with the weapons aspects of the project. He assumed responsibility for the research direction of the pile chemistry section of the laboratory in January, 1946. Dr. Stewart joined the chemistry division of the metallurgical laboratory of the Chicago University in 1944, as a member of the plutonium recovery group. He was appointed group leader, a position which he held for one year before becoming assistant chief of the chemistry section. At that time Dr. Glenn T. Seaborg was section head and Dr. Winston M. Manning, now head of the Argonne chemistry division, was associate section chief. In 1946 he participated in atomic weapons tests at Bikini Atoll in the Pacific. Following the tests he joined the University of California Radiation Laboratory at Berkeley while completing studies there for his PhD degree in biochemistry. In 1952 he was appointed assistant director of the chemistry division, a position which he held for two years before returning to full-time laboratory research. From 1957 to 1958, he was at the Atomic Energy Research Establishment, Harwell, where he worked with Mr. A. A. Smales, head of the analytical chemistry section, in determining the exact amount of uranium in deep sea waters.

MR. JACK CARLIN, president of Atomic Associates, Inc., Cambridge, Mass., which last spring became the sales subsidiary of Baird-Atomic Inc., has been appointed manager of the parent company's newly-established atomic instrument division. Mr. Carlin will direct sales and service activities, nuclear instrument engineering, product planning and the preparation of manufacturing requirements. Succeeding Mr. Carlin as president of Atomic Associates is **MR. RICHARD E. O'TOOLE.**

Alco Products, Inc., of Schenectady, New York, have appointed **MR. HANS SCHWARZ** as manager of general engineering and development in the firm's research and development department. Since 1955 Mr. Schwarz has been a senior project engineer. Born in Germany 38 years ago, he was educated in New York and before joining Alco worked for the Elliott Company in Jeannette, Pa.

Another appointment announced by Alco Products is of English-born **MR. JOHN GRONAN** as head of their nuclear power engineering department. In this capacity he will co-ordinate and supervise the firm's nuclear projects. Mr. Gronan, now an American citizen, was formerly associated with the Cunard Line and the engineering consultants, Burns and Roe Inc. He was recently working on the plutonium producing reactor at the USAEC's Hanford, Washington, plant.

NUCLEAR NEWS

- **The Halden Reactor Opened** *(This page)*
- **N-Propelled Helicopter** *(Page 558)*
- **Another Amalgamation** *(Page 559)*

Royal Ceremony

THE boiling heavy water reactor at Halden, Norway, which went critical at the end of June was formally dedicated recently by H.M. King Olav of Norway. The reactor, which has been built by the Norwegian Institutt for Atomenergi, is to be used for an OEEC sponsored programme of research and experiment in which Norway is being joined by Austria, Denmark, EURATOM (representing Belgium, France, Germany, Italy, Luxembourg and the Netherlands), Sweden, Switzerland and the United Kingdom. The joint project has been organized by the OEEC European Nuclear Energy Agency. Maximum design output of the reactor is 20 MW.

Atmospheric Studies

REPORTING on a study of radioactivity in the atmosphere, carried out from 1953 to 1958, Argonne National Laboratory scientists state that the stratosphere, which contains 15 per cent. of the total air in the earth's atmosphere, held four and one half times its natural background level of radioactive carbon (carbon-14) in the 1958 summer because of atomic tests. In contrast, the concentration of carbon-14 in the troposphere, which contains 85 per cent. of the air of the atmosphere, increased only 15 per cent. during the five year period. Atomic tests released an estimated 1,300 lb of carbon-14 into the entire atmosphere from 1953-58. The total, stratospheric content of tritium was four times the natural level on January 1, 1958. Atomic tests added approximately 26.5 lb of tritium to the 6.6 lb already present.

Rocket Reactors

AT the Commonwealth Symposium on spaceflight recently held in London, Dr. O. H. Wyatt, MA, PhD, AMIMechE, of the Hawker Siddeley Nuclear Power Co., Ltd., read a paper on "The Performance of Nuclear Thermal Fission Rockets." In this he considered the use of cylindrical rocket reactors of two designs. One, 5 ft in diameter and 5 ft high, would use plutonium-239 as fuel and the other, 12 ft in diameter and 12 ft high, U-235 as fuel. Both would be associated with hydrogen or ammonia as propellant. The minimum all-up weights of nuclear rockets with graphite-moderated thermal reactors, operating at 2,500°C., with a maximum propellant temperature of 2,000°C., would range from 250,000 lb for plutonium fuel and hydrogen propellant, to 3,000,000 lb for uranium fuel and ammonia propellant. The corresponding thrusts would be 630,000 lb and 6m. lb. The corresponding burn-out velocities, at no gross payload, are 33,500 ft/sec (which is sufficient for orbiting at about 500 miles altitude), and 21,500 ft/sec, which is less than the minimum orbiting velocity. Comparison with chemical rockets of the same all-up weight shows that hydrogen propelled nuclear rockets are equal to or better than the best future chemical rockets and very much superior to current chemical rockets. Nuclear rockets with ammonia propellant have performances intermediate between current and future chemical rockets. Since nuclear rockets have lower mass ratios, their performance relative to a chemical rocket improves for increasing payloads.

Standstill

BECAUSE of protracted labour disputes the Motherwell Bridge and Engineering Co., Ltd., recently suspended work on the nuclear power station at Hunterston, Ayrshire. The company are responsible for the construction of the reactor vessel and steam raising plant. The company warned that it might suspend work earlier this year when it announced that within the space of seven months there had been some 15 unofficial strikes in which some 55,000 man hours had been lost, representing 14 per cent. of the hours worked in the period. Further trouble was encountered in June when 125 day shift workers were suspended for "persistent industrial misconduct." As a result of the strikes work on the site is now some nine months behind schedule. Reason for the strikes is given by one union as being that labourers and unskilled men were earning more than engineers, and welders were earning even considerably more. The basic wage on the site is £15 a week; average earnings however are said to be between £25 and £30, and in some cases, with overtime, £50.

Canadian School

THE first class in the newly-established reactor school at Chalk River, Ontario, Canada, begins on February 1st, 1960. Canadian and foreign engineers and scientists may apply for admission to the school. Courses will be of 12 weeks' duration and each course will have places for 20 students. Instruction will put special emphasis on heavy water moderated natural uranium fuelled reactors. Candidates for the school must have a degree in physics, engineering physics, chemistry, metallurgy or engineering. Director of the school is Dr. D. A. Keys, scientific adviser to the president of Atomic Energy of Canada Ltd. Lecturers will be senior executives and members of the scientific staffs of the various Atomic Energy of Canada divisions. Application forms can be obtained from the secretary of the school, Dr. W. R. Livingston, or from Canadian embassies and consulates.

IAEA Conference, Vienna

The president of the third annual conference of the International Atomic Energy Agency, Dr. Hiroc Furuuchi, of Japan, with the Agency Director-general, Mr. Sterling Cole (*left*) and the Secretary-general, Mr. Paul Jolles (*right*). The conference which was held in the former Imperial Palace, Vienna, was attended by delegates from 70 member states and by representatives of the United Nations, specialized agencies and several other international organizations. Reviewing the work of the Agency during the past year, Mr. Cole stressed the "inescapable" need for international action in the fields of atomic assistance, atomic safety and atomic security. During the forthcoming year the Agency plans to spend something like $8,233,000, $5,843,000 of which will be used for regular expenses, $333,000 for the Agency's laboratory facilities (construction of the laboratory was started during the conference, a special ceremony marking the occasion being attended by the head of the U.S. Atomic Energy Commission), $57,000 for the Agency's mobile radioisotope laboratories, and $2,000,000 for technical assistance and the fellowship and training programme. Achievements of the Agency during the past year included the sending of experts to various countries for the purpose of studying their needs in the nuclear field, the selection of 600 students from 42 countries for training under the aegis of the Agency, and the implementation of the Agency's scientific and technical information programme

Marine Project

THE GEC Ltd., have published a paper by Mr. M. C. Hartnell-Beavis, BSc, chief projects engineer of their atomic energy division, on "A Nuclear Reactor Installation for Marine Use." It describes why GEC decided to develop the gas-cooled, graphite-moderated reactor for marine use, and how an installation of 22,000 s.h.p. can be fitted into a containment vessel only 44 ft long, 35 ft wide and 37 ft high. The design of such an installation, which incidentally weighs under 2,000 tons, is outlined in the paper and a table of its principal parameters included. Comparisons between the costs of a 100,000 ton tanker and a fast liner with accommodation for 5,000 passengers and crew are made. It is estimated that in the latter case a saving of £3,000,000 could be made a year by using nuclear instead of conventional propulsion.

IAEA Aid Given

THE International Atomic Energy Agency is sending experts to Denmark, Tunisia, Turkey and to the United Arab Republic to assist in the nuclear programmes of these countries. Also, an IAEA preliminary survey mission is to visit countries in the Middle East and Mediterranean region for the purpose of assessing the requirements of these countries in the way of assistance from the Agency. In Denmark, an IAEA expert will work with the metallurgy group of the reactor division of the Danish Research Establishment at Riso, near Copenhagen. Experience in non-ferrous metallurgy in Denmark is limited and the Danish Atomic Energy Commission sought the help of the IAEA in making good this deficiency. In Tunisia, the expert will be an agricultural chemist, he will work at the Institute of Botany and Agronomy where he will advise and assist in the application of radioisotope techniques to current research projects at the Institute. He will also lecture at the School of Agriculture. Another scientist sent to Tunisia will be an expert in medical and biological applications in radioisotopes. To ensure the work of the experts sent to Tunisia, the IAEA is supplying the country with radiation equipment worth over $8,000. Similar equipment is also being sent to Turkey, which will be visited by an expert who will assist local scientists and establishments in setting up a pioneer laboratory for agricultural research. A health physicist will be sent to the United Arab Republic.

The Chinese Learn

TOURING China recently has been a Russian "Atoms for Peace" exhibition. It showed Soviet achievements in nuclear applications in agriculture, medicine, and industry. Training courses for scientific and technical workers held in conjunction with the exhibition were well attended.

Training the Young

WHAT some employers' organizations and joint bodies are doing in the way of providing training services for the benefit of the firms in their industries is described in a booklet, entitled "Training Services in Industry," just published by the Industrial Training Council. This is the first booklet published by the Council. The Council was set up a year ago to keep under review the recruitment and training of workpeople and to encourage, assist and inform industries about these matters. It is devoting attention in the first place to the problem presented by the coming "bulge" in schoolleavers so as to ensure as far as is possible that industry's training arrangements will be adequate to enable the best use to be made of the increased number of young people who will be entering employment over the next few years. Copies of the booklet may be obtained from the Council, 36, Smith Square, London, S.W.1., price 1*s.* 6*d.*

U.K. Firm in Canada

EVERSHED & VIGNOLES Ltd., instrument manufacturers and electronic instrumentation engineers, of Chiswick, have announced the re-organization and enlargement of their Canadian activities by the formation of a new company which is to be known as Evershed-Powertronic Ltd. To operate from Toronto this company will provide a complete, coast to coast sales and service organization for the installation of automatic electronic control equipment.

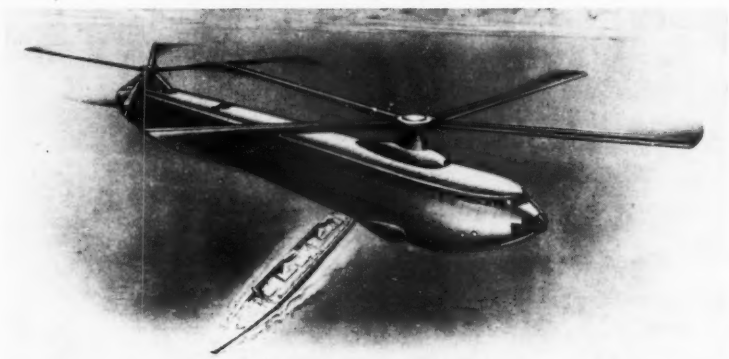
MSc (Nuclear)

THE first Master of Science degrees in nuclear sciences to be awarded by the Technion, the Israel Institute of Technology, will go to four graduate students due to complete their research projects early in 1960. Their projects include research into the heat transfer problems of power reactors designed for the useful generation of electric power, the problem of boiling water reactors in the field of reactor physics, and the solution of pertinent mathematical equations of electrical techniques.

Journals for IAEA

THE Government of Australia has presented the International Atomic Energy Agency with complete sets of ten of the country's leading scientific and technical journals, as well as with free subscriptions for them. The IAEA library is at present growing at a rate of approximately 500 additions per week. At the same time, it is getting requests from all over the world for information on specific problems of applying nuclear energy for peaceful purposes.

Helicopter of the Future



Bell Helicopter Corporation of Fort Worth, Texas, recently completed a feasibility study for a nuclear-powered helicopter. The aircraft would have a 300 ft long fuselage and would weigh 500,000 lb. Cruising speed of the helicopter would be more than 200 mile/hr

Glove Box Hoist

A SPECIAL remotely controlled glove box hoist has been designed by the Hawker Siddeley Nuclear Power Co., Ltd. It has a lifting capacity in its present form of 3 cwt. and such loads can be lifted 5 ft at speeds ranging from 0 ft to 12 ft/min. The unit height from the top of the channel rails supporting it to the centre line of the hook is only 10½ in., considerably less than that of normal hoists for the same duty. With gantry mounted, the hoist hook can drop to within 7 in. of the ends of a glove box or similar housing and to within 10 in. of its sides.

TV Documentary

FEATURED on U.S. television recently was "Enter with Caution: The Atomic Age," a dramatized account of a real life accident in a radioactive isotope laboratory. Presented in two parts, the programme showed how the accident affected the people directly involved, the reaction of the local community to the accident, and the broad implications of radioactivity.

Soviet Conference

OVER 300 papers on the results of the application of nuclear energy in various branches of Russian science and technology were presented at a conference recently held in Tashkent, capital of the Uzbek Republic, U.S.S.R. Nearly a thousand scientists attended the conference. Tashkent is the home of one of Russia's leading nuclear research centres. It is installed with the latest equipment and has the largest gamma radiation sources in Russia.

New Address

THE Bristol branch office of the English Electric Co., Ltd. has been moved to a new address. It is at the Equity and Law Building, 36-38, Baldwin Street, Bristol, 1. The telephone number is Bristol 27304.

Consortia Unite

AN agreement has been made between the GEC, Ltd./Simon Carves Ltd., atomic energy group and Atomic Power Constructions Ltd., to collaborate in the design and construction of nuclear power stations in the United Kingdom. The two groups will submit joint tenders for Dungeness and for further stations in the British nuclear power programme. This development does not affect existing contracts and commitments of the two groups, either in the United Kingdom or overseas. This is the second collaborative agreement to be made between nuclear power consortia, the first being between the AEI-John Thompson Nuclear Energy Co., Ltd., and the Nuclear Power Co., Ltd.

Looking Ahead

" THE Atomic Industry—a preview of the 60s' " is the theme for the annual conference of the Atomic Industrial Forum, in Washington, D.C., during early November, Papers on: Prospects for Non-Power Reactor Applications; Problems in Industry-Government Relations; Patent and Liability Problems; Experience for Operating Power Reactors; Siting of Nuclear Power Reactors; Radiation Protection Control Problems; Atomic Progress Abroad; Evaluating Reactor Concepts and Systems; New Radioisotope and Radiation Applications; The Euratom Programme and Technical and Economic Prospects for Nuclear Fuels will be presented.

School Expands

THE International School of Nuclear Science and Engineering at the U.S. Atomic Energy Commission's Argonne National Laboratory is to expand and broaden its programmes. Following the completion of the ninth session of the school it will, in February of next year, become known as the International Institute of Nuclear Science and Engineering, and will give greater emphasis to advanced training. It will offer less background instruction of the type which is now generally available in colleges and universities. Additional teaching and laboratory facilities will be provided to cater for this change. Minimum qualification for admission to the Institute will be the equivalent of a master's degree in an American university. Successful candidates will be instructed in applied nuclear science. Holders of higher qualifications will be expected to make significant contributions to the overall Argonne scientific research programme.

Russian Reactor Building

An experimental light water moderated and cooled power reactor is under construction at Voronezh in the U.S.S.R. The illustration shows the main building construction site

NUCLEAR NEWS

Reactor for Naval Students

THE Babcock and Wilcox Co., of New York, have been awarded a contract by CAMEN, an Italian Government-owned research and training agency, for the supply of a 5 MW research reactor. This will be used for training engineering students of the Naval Academy, Livorno, and of Pisa University. It is due to go into operation in early 1961.

World Bank Loan Signed

Signatories to the $40m. loan made by the International Bank of Construction and Development to an Italian government agency for the construction of the 150 MW BWR plant on the Garigliano River halfway between Rome and Naples. The loan will cover about 60 per cent. of the total cost of the plant and will last for a period of 20 years. GEC of New York are to supply the reactor

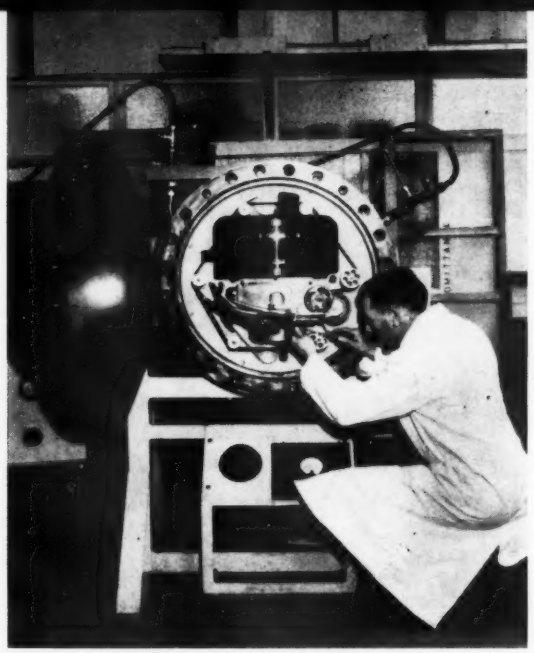
Book Review

Fundamentals of Nuclear Energy and Power Reactors, by Henry Jacobowitz. Size 9 in. × 6 in. × 118 pp. illus., Published by John Rider Publisher Inc., New York. (Distributed in United Kingdom by Chapman and Hall Ltd. Price 24s.)

A better title for this book would be "American Fundamentals of Nuclear Energy and Power Reactors" for in the reactor section only systems designed and developed in the States are described. The Calder Hall type of reactor is ignored. Indeed it is virtually suggested that a reactor using natural uranium as fuel is of little value. Furthermore, the idea of using a gas coolant receives little more than a passing reference. To give such poor treatment to a reactor concept which is the basis of a whole series of important industrial reactors and in which the Americans themselves are interested seems a serious defect in a book that purports to deal with fundamentals. In the field of American reactors the book does an excellent job describing various systems in easy-to-understand language with the help of clear, simple drawings. The reactors described include the Brookhaven National Laboratory Reactor, the Bulk Shielding Reactor at Oak Ridge (this is a light water moderated pool reactor), the Argonne CP-5 (a heavy water moderated reactor), the Armour Research Reactor, the Pressurized Water Reactor and its industrial applications (there is quite a lengthy description of the Shippingport plant), and the boiling water and sodium graphite reactor concepts. There are also references to breeders and homogeneous reactors. Before dealing with the reactor systems, the book gives a brief but fairly full description of atomic structure and nuclear fission. T.R.

Nuclear Instrument Makers

A visit to
Plessey Nucleonics Ltd.



Assembling a precipitator for BSD equipment

PLESSEY Nucleonics Ltd., have been in existence only since 1956 but already they have had to expand their premises at Northampton to almost double the original area occupied, and to nearly double their staff. Such is the rapid growth of the nuclear instrument industry.

The principal product of Plessey Nucleonics is burst slug detection equipment for nuclear power reactors. They also make equipment for the complete instrumentation of reactors, neutron flux scanning apparatus, and a wide range of radiation detectors and monitors.

The premises at Northampton comprise not only fully-equipped production workshops and equipment assembly areas, some of which are specially air-conditioned, but also comprehensive research and development facilities. Indeed, a considerable proportion of the work undertaken at Northampton is in research and developments and, over one-third of the staff are engaged in these spheres.

Food monitor (Type PNI 1045) made by Plessey Nucleonics Ltd.

Neutron Generator

There are physics, mechanical engineering and electronics laboratories, together with special laboratories for radiation studies and detector development. Provision is being made for "hot" cells in which work with highly radioactive materials can be carried out, and the company already has its own neutron generator—an electrostatic unit with a maximum capacity of 10^9 neutrons/sec.

To provide a background to work carried out in the laboratories and also to provide an extra service for clients, the company has a large mathematics group—large in relation to the overall size of the company

The company, in addition, has the use of the facilities of its associated companies, which comprise the wide-embracing Plessey Group. There is for instance some collaboration between Plessey Nucleonics and the Plessey Chemical and Metallurgical laboratories at nearby Caswell.

Plessey Nucleonics supplied the burst slug detection equipment installed in the Calder Hall "A" and "B", Chapelcross and Marcoule, France, nuclear power stations. Improved versions of this equipment are to be used in the Central Electricity Generating Board nuclear power stations at Bradwell, Hinkley Point and Trawsfynydd, and also in the station being built at Latina, Rome.

One of the results of the research programme at Northampton has been the development of a burst slug detection system for heavy water reactors. This system is to be installed in the United Kingdom Atomic Energy Authority reactors DIDO and PLUTO at Harwell and the DMTR at Dounreay. Orders for it have also been received from two European countries.

In the radiation detection and monitoring field Plessey's have a large and extensive programme. One of the most recent and interesting developments is the low energy gamma ray monitor for detecting plutonium in body wounds.

Many of the radiation monitors are designed with Civil Defence requirements in mind. Among them are a special milk monitoring apparatus and water contamination measuring equipment. In the latter, water is passed through an ion exchange resin bed which removes the radioactivity. A detector in the resin measures the accumulation of total activity. Specific activity is then related to the differential of the instantaneous counting rate.

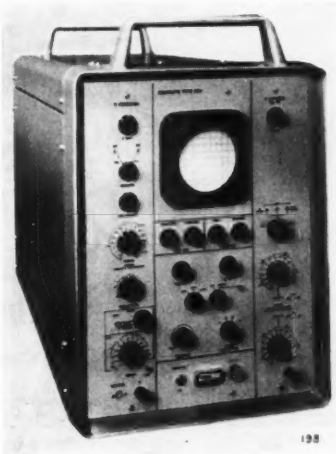
Other monitors are available for more general purposes. Much of the equipment is made in both standard and portable models.

One of the laboratories at Northampton is devoted to the development of flux counters and ionization chambers.

Equipment and Materials

Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

Storage Oscilloscope



Cawkell's "Remscope"

The "Remscope" storage oscilloscope made by Cawkell Research and Electronics Ltd., greatly extends the range of measurements and observations possible without recourse to photographic recording. Previous storage oscilloscopes made by Cawkell's have used the American "Memotron" cathode-ray tube and their performance has been limited by the relatively slow response of that tube. Now, with the advent of the English Electric type E702 storage and display tube, this limitation no longer applies and the "Remscope" has been designed to make the fullest use of the tube. The E702 tube contains a storage system which allows a transient to be stored for up to a week and displayed for a limited period during that week. In the "Remscope" this display time (which may be taken piecemeal) exceeds 15 min and may, on all but the fastest signals, be extended to nearly 2 hr. Some slight reduction of brightness occurs on the longest display times but an adequate display is still obtained. In order that the maximum use may be made of the stored image, the display may be left off until required (storage only occurring) or may be switched on automatically when a signal is received. The persistence of the display can be varied from a few seconds up to 15 min. This facility is particularly useful when comparing one event from a series with its predecessor. By adjusting the persistence the first signal can be made to fade as the third appears and so on. Varying the setting will allow other sequences to be produced. Erasure is rapid and may be obtained by depressing an internal press-button or making an external circuit. Initially a single-channel wide-band Y amplifier with differential d.c. inputs will be fitted. To enable it to be replaced by different units in the future this amplifier is of a plug-in type. As the oscilloscope is intended primarily for the study of transient signals great care has been taken to ensure reliable and easy triggering. **(NOV 1)**

Cut along here

To: NUCLEAR ENERGY ENGINEER
147 Victoria Street, London, S.W.1

Please send further details of the following items in the EQUIPMENT and MATERIALS *feature for Nov., 1959*

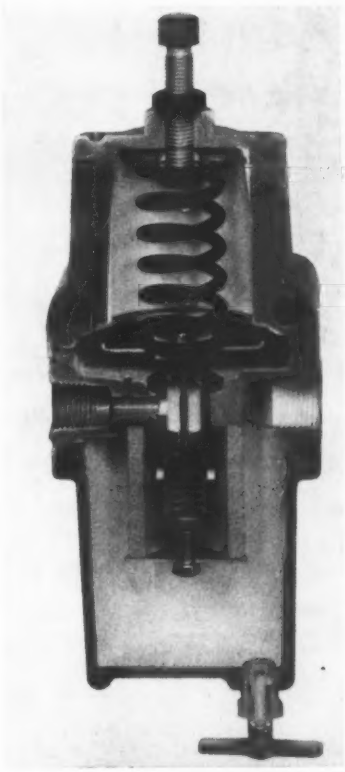
Item No's ....
....

IS THIS ENQUIRY CONFIDENTIAL? YES | NO

Enquirer's Name .....
Position .....
Firm .....
Address .....

Air Filter Regulator

Made available by Crosby Valve and Engineering Co., Ltd., the No. 77 Mason Neilan air filter regulator set comprises a large capacity dripwell porus ceramic cartridge type filter, accurate pressure reducing valve and safety relief valve, all in one compact light-weight unit. The body is of die cast aluminium with two mounting bolt holes. An outlet pressure gauge can be supplied fitted when necessary and if necessary the outlet connection can be orientated in three alternative positions. Elimination of alignment problems has resulted in a remarkably flat pressure/flow curve over a very wide range. The set can be supplied with or without outlet and/or inlet pressure gauges. The maximum inlet pressure is 250 lb/sq.in. reducing pressure range is 5-40 lb/sq.in; inlet and outlet connections screwed female; weight 2½ lb, and overall height 8¾ in. **(NOV 2)**



Model of No. 77 Mason Neilan Air Filter

Detecting "Live" Faults

A new bolometer, operating on the principle of a change of resistance being produced in a strip of gold leaf when exposed to infra-red rays, has been developed by H. Tinsley & Co., Ltd., scientific instrument manufacturers of South Norwood, London. Its uses in engineering concern detection of hot spots in machinery and equipment which it is not possible or convenient to touch or approach near enough to use other types of instruments. It can, for example, detect bad joints in high voltage cables whilst the high voltage is ON, this requiring no more than focusing the joint on the bolometer window. It also applies to such things as equipment emitting a high level of radio-activity, or where local atmospheric conditions create a potential danger. It can be used for taking temperatures on rotating parts of machinery. There are numerous other specialized applications. The bolometer operates by the change in resistance produced in a strip of gold leaf when infra-red rays fall upon it. The gold leaf strip coated with lamp black so that it will absorb and not reflect the infra-red rays that fall upon it, is about 1mm in width held across three supports so that it makes two equal arms making electrical contact at the points

Tinsley's New Infra-Red Bolometer

of support. These form the arms of a Wheatstone Bridge network. The assembly is mounted in a small draught free box. Over one arm of the gold leaf there is a window, transparent to infra-red rays of wavelengths up to 10 μ. The whole unit is placed at the focal point of a concave cylindrical reflector about 5 in. aperture. It is arranged so that rays from a distant object can be focused on the arm of gold leaf immediately behind the window of the assembly. The gold leaf forms two arms of a Wheatstone Bridge. The other two arms comprise a pair of fixed ratios with a slidewire connected between them. The sliding contact of the slidewire can be adjusted so that the bridge is balanced. The bridge is energized by a 1,000 c/s oscillator using transistors and miniature components and the detector points of the bridge are connected to the input of an amplifier also using transistors and miniature components. The output from the amplifier is connected to a pair of headphones and the bridge may be balanced by adjusting the slidewire until there is silence in the phones. A scale is fitted to the slidewire which can be calibrated in terms of the energy entering the bolometer. The bolometer is sensitive to very small changes in the radiation entering it and will detect objects which are only a few degrees hotter then the background. A human body can very easily be detected at a distance of 20 ft, in a room of ambient temperature about 25°C. Objects at a distance of several miles can also be detected if they are large enough; for example a ship's funnel can easily be detected at a distance of several miles provided it can be focused on to the bolometer with sufficient accuracy. The radiation from clouds can also be detected without difficulty. The instrument is cylindrical, about 14 in. in length and 7 in. in diameter, provided with hand grips. There is an eyepiece through which the image of the object may be seen and focused on the window of the bolometer. The slidewire control knob is conveniently placed so that it can be operated by the forefinger and thumb of the right hand without removing it from the hand grip. The slidewire is in the form of a ten-turn helical potentiometer, and the scale has a ten-turn counter. The instrument can also be mounted on a tripod. This may be more convenient when observations have to be made on a distant object or over a period of time. **(NOV 3)**

Analysis Simplified

Designed for the specific purpose of measuring minute impurities in solid substances, the Metropolitan-Vickers MS7 mass spectrometer, which has recently been put into production, will be of invaluable use in the fields of science and engineering where it is necessary to use materials of the highest purity, such as in nuclear engineering, semi-conductor research and production and in the development of most non-ferrous metals and alloys. Some of the materials which have been successfully analysed down to 0.01 p.p.m. with the prototype model include uranium, reactor grade graphite, germanium, selenium, silicon, gallium-arsenide, magnesium, titanium, tungsten, iron, copper, aluminium, tin and nickel-chromium alloys. The type MS7 mass spectrometer is a double focusing instrument of the Mattauch type, in which positive ions, representative of the sample composition, are produced when a high-voltage spark occurs between two electrodes of the sample material placed closed together in vacuum. After passing first through an electrostatic analyser and then through a magnetic analyser the ions come to focus according to their mass, but irrespective of their initial energy, as a series of lines on a photographic plate. For the analysis of impurities in solids the photographic plate is used as an integrating device, and a series of exposures of gradually increasing length are taken (a rack mechanism allows up to 10 exposures to be recorded on the same plate and the exposure is accurately determined by the total integrated charge falling on the monitor collector). The concentration of the impurity is estimated from the intensity of the lines on the longer exposures, and with this technique concentrations down to the level of 0.01 p.p.m. can be estimated. The method is particularly useful for giving a general picture of the impurities in a solid.

The MS7 Mass Spectrometer

The whole mass range from 7-240, covering all elements, can be recorded in a single exposure of the photographic plate. Compared with emission spectroscopy the spectra are simpler and the elements easier to identify. Moreover, qualitative and semi-quantitive analyses can be carried out without extensive calibration. **(NOV 4)**

New Radiation Sources

Tracerlab, of Waltham, Massachusetts, have announced the availability from stock of radioactive clathrates, a unique new source of radiation which combines unusual safety with high specific activity. The radioactive clathrate, is a crystalline form of the chemical hydro-quinone combined with gaseous krypton-85. The krypton gas is not chemically bound to the hydroquinone but is mechanically trapped within cages formed by the molecular structure of the crystal (a chemical clathrate can be envisioned as roughly similar to the common playground apparatus, the child's jungle gym). Clathrates can contain more than 30 times the radioactivity of the same volume of gaseous krypton supplied by Oak Ridge. A clathrate may be considered as a solid source of krypton-85 (a nearly pure beta emitter with a half life of 10.3 years) and used as such or, it may be employed as a convenient source of gaseous Kr85 since controlled release of the krypton can be obtained by heating or chemical dissolution of the cage structure. Clathrates may be employed as a radiation source for thickness gauging, production of bremsstrahlung or X-rays, static elimination, light sources, and many other interesting applications. **(NOV 5)**

MERLIN

(*Continued from page 537*)

circuit or if a danger signal is received from a gamma ray detector in the secondary coolant pipes. This minimizes the possibility of radioactive products getting into Aldermaston lake via a leak between the primary and secondary sides of the heat exchangers.

No effort has been spared in the safe operation of MERLIN. Standards of safety adopted have been approved by the UKAEA Reactor Safety Branch.

When the reactor is operating power output will be measured by four ion chambers; in addition, at very low power levels, a fission chamber is used. The ion chambers are connected to one linear current measuring circuit, one logarithmic current measuring circuit and two shut-down amplifiers.

In addition to the instruments on the reactor, various monitoring and measuring instruments are installed in other parts of the reactor system, in the water systems, in effluent outlets and in the lake. Coupled to these instruments and to the automatic safety circuits which shut down the reactor there is a comprehensive warning system.

The safety circuits are tripped off when:—

(*a*) excess power is indicated either by one or other of the shut-down amplifiers or by the logarithmic current amplifiers;

(*b*) the reactor period is too short;

(*c*) the cooling water temperature is too high;

(*d*) the cooling water flow is inadequate when the power output is over 100 kW.

(*e*) The pool water level is too low;

(*f*) the electricity mains fail; or

(*g*) any of the five emergency shut-down buttons are pressed.

The safety circuits are also tripped when the fission chamber counts at a too high or a too low rate. This circuit does not function, however, when the control system is set to "operate" and the ion chambers are giving a satisfactory signal.

In addition to the safety measures provided by the instrumentation there are interlocks on the control system and experimental facilities which govern the conditions under which normal operation and the principal maintenance operations may be carried out.

Another aspect of safety is covered by design features incorporated in the reactor aimed at preventing accidents that might occur through, for example, a too rapid rise in reactivity due to overquick fuel loading.

The staff required to operate MERLIN will consist of a physicist, who will effectively be the reactor manager, supported by three operators, one of whom will be part-time, and one assistant for record-keeping and general duties. All these, except the assistant, have had experience of operating research reactors. This basic staff will be supplemented by reactor supervisors, who will be experienced members of the laboratory staff and have all spent some time working at Harwell; their duties will be to ensure that the procedures being followed throughout the reactor system are as ordered in the reactor operating instructions and generally to supervise all operations with, and about, the reactor. All experiments using MERLIN are reviewed by a Safety Committee to ensure that they do not involve a potential hazard to the system; this committee includes members of the laboratory staff who have no direct interest in the reactor and experienced scientists from outside the AEI Co. All modifications to the reactor, or changes in method of operation, are similarly reviewed by a panel, and can only be authorized by this panel.

Regular Testing

Another panel has the duty of advising on those aspects of the reactor core concerned with how sub-critical it would be, under any postulated circumstances. Testing of the reactor is carried out regularly according to a set schedule and the reactor system is maintained by teams of electrical and mechanical engineers who will also be engaged on the development of equipment for use with the reactor.

When research is undertaken the number of staff vary according to the nature of the research.

Cost of the reactor including fuel elements is about £600,000. Annual operating costs amount to about £100,000.

LETTER TO EDITOR

SIR: I should like to comment on the rather sweeping statements made in the May and June, 1959, issues of NUCLEAR ENERGY ENGINEER. It is asserted by "Nuclearist" that no first degree courses in British universities mention nuclear energy. This I feel is not strictly accurate. I recently completed my first year reading Engineering at Cambridge University, and so can give you relevant information concerning the course. Two years ago the Materials lectures were revised to include a brief mention of nuclear energy, fission and fusion. The mathematical concept of converting mass into energy is, as you say, simple enough. The course includes calculation of true mass defect (and hence binding energy) from atomic mass units. Also, the representation of nuclear fission and nuclear fusion on the graph of atomic number plotted against binding energy per nucleon. Packing fraction, we were informed, is now out of date, though we were told what it was. Nuclear structure, isotopes, isotomes, isobars, mistability, alpha, beta and gamma radioactivity, use of moderators, and evolution of energy on build up of an atom from its fundamental particles, were all mentioned briefly. Admittedly the course does deal only very briefly with these matters, but nevertheless they are at least mentioned. If you want more nuclear energy in the already full university courses, what do you suggest should be cut out to make way for it? Personally I find it hard to conceive exactly what could usefully be pruned from the course, which for us is general and unspecialized.

Yours faithfully,
J. G. JELLETT.

Caius College,
Cambridge.

"Nuclearist" writes: First of all, I will admit to being sweeping. The matter of nuclear education is something which needs action in this country, and no words from the press will carry weight unless they are dramatic. But dramatic words need not be inaccurate ones. At no place did I state that no first degree course in British universities mention nuclear energy. I was, in fact, putting in a plea for a more realistic approach to the subject. Most students to-day know the rudiments of atomic structure, but fail to appreciate how this has any bearing on power, propulsion, isotope applications, and so on. Further, I pleaded for a bolder approach to the experimental side of the subject, without which no scientific course can be considered satisfactory. Mr. Jellett has, of course, struck a very sensitive nerve when he asked what can be left out of a syllabus to make room for more recent work. This is something which has always been a thorny problem, and will always continue to be. There were times when the ionic hypothesis, evolution, relativity, hormones, electron microscopy, and a thousand and one other topics, did not appear on university curricula. Organic and inorganic chemistry have grown out of all recognition even during the last 15-20 years, but the degree student's textbooks make a valiant effort to keep abreast of the times.

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